

INTERNATIONAL STANDARD



Measuring relays and protection equipment –
Part 27: Product safety requirements

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**Measuring relays and protection equipment –
Part 27: Product safety requirements**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MEASURING RELAYS AND PROTECTION EQUIPMENT –

Part 27: Product safety requirements

FOREWORD

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This commented version (CMV) of the official standard IEC 60255-27:2023 edition 3.0 allows the user to identify the changes made to the previous IEC 60255-27:2013 edition 2.0. Furthermore, comments from IEC TC 95 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 60255-27 has been prepared by IEC technical committee 95: Measuring relays and protection equipment. It is an International Standard.

This third edition cancels and replaces the second edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) conflicting statements removed;
- b) scope clarified and statement added that all clauses of the standard are required not just type tests;
- c) terminology, definitions and documentation requirements aligned with IEC 60255-1;
- d) alignment with IEC 61010-1, e.g. HLV definitions;
- e) ingress protection clarified;
- f) dielectric and impulse tests added to mechanical and environmental test requirements;
- g) insulation resistance requirements updated for alignment with other product safety standards;
- h) sample testing removed;
- i) short time limiting thermal overload added;
- j) resistance to mechanical stress added;
- k) low-power voltage and current transformer ports added;
- l) Annex C tables updated to align with base standards;
- m) Annex D voltage dependent resistors and radio transmitters added;
- n) Annex G for risk assessment added.

The text of this International Standard is based on the following documents:

Draft	Report on voting
95/516/FDIS	95/526/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60255 series, published under the general title *Measuring relays and protection equipment*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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INTRODUCTION

~~In order to demonstrate that the equipment is safe, it was previously necessary to refer to general safety standards such as IEC 61010-1 in addition to IEC 60664-1.~~

~~These general safety standards specify requirements for general product types or product families in order to reduce the risk of fire, electric shock or injury to the user. The product types do not include measuring relays and protection equipment. These standards also take into account single fault conditions.~~

~~Reference to all these various standards created confusion due to conflicting requirements, for example, different clearances, creepage distances and test voltages etc., for the same rated voltages.~~

~~The aim of this standard is:~~

- ~~• to remove confusion due to conflicting requirements between existing standards;~~
- ~~• to achieve a uniform approach throughout the international industry for measuring relays and protection equipment.~~

~~This product safety standard for measuring relays and protection equipment takes the general product safety standards and IEC 60664-1 as the base, defining those issues specific to measuring relays and protection equipment.~~

This document specifies the safety requirements that are generally applicable to all equipment within its scope. These requirements may be supplemented by general product safety standards and IEC 60664-1.

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MEASURING RELAYS AND PROTECTION EQUIPMENT –

Part 27: Product safety requirements

1 Scope

This part of IEC 60255 ~~describes~~ specifies the product safety requirements for measuring relays and protection equipment having a rated AC voltage up to 1 000 V ~~with a rated frequency up to 65 Hz~~, or a rated DC voltage up to 1 500 V. Above these limits, IEC 60664-1 is applicable for the determination of clearance, creepage distance and withstand test voltage.

This document ~~details~~ specifies essential safety requirements to minimize the risk of fire and hazards caused by electric shock or injury to the user and property. This document specifies only product safety requirements; functional performance of the equipment is not covered. **1**

~~This standard does not cover the safety requirements of installations.~~ This document covers all the ways in which the equipment ~~may~~ can be mounted and used in ~~cubicles~~ cabinets, racks and panels, ~~and also retesting~~. This document also applies to auxiliary devices such as shunts, series resistors, transformers, ~~auxiliary control panels~~, display devices, etc., that are used in conjunction with measuring relays and protection equipment and are tested together.

It is possible that ancillary equipment such as network switches used in conjunction with measuring relays and protection equipment ~~may need~~ needs to comply with additional safety requirements.

~~This standard is intended to describe only product safety requirements; therefore, functional performance of the equipment is not covered.~~

~~Functional safety requirements, including EMC functional safety, are not covered by this standard. Functional safety risk analysis is not within the scope of this product safety standard.~~

This document does not specify the implementation of individual equipment, circuits and components.

~~The object of this standard is to have a comprehensive standard that covers all aspects of product safety and the related type and routine tests, for measuring relays and protection equipment.~~

This document applies to equipment designed to be safe at least under the following environmental conditions:

- indoor use;
- altitude up to 2 000 m, in accordance with IEC 60255-1;
- ~~— external operating temperature range, in accordance with IEC 60255-1;~~
- rated ambient temperature range, in accordance with IEC 60255-1;
- maximum external relative humidity ~~95 %, non-condensing~~, in accordance with IEC 60255-1;
- ~~— supply fluctuations in accordance with IEC 60255-1;~~
- operating range of auxiliary energizing voltage in accordance with IEC 60255-1;
- applicable ~~supply~~ overvoltage category;
- ~~— external pollution degree 1 and external pollution degree 2.~~

- applicable pollution degree of the intended environment (pollution degree 2 in most cases).

~~The equipment will normally be installed in a restricted access area within a power station, substation or industrial/retail environment. The environmental conditions specified for the equipment in IEC 60255-1 apply. This standard considers the normal environmental conditions of corrosion caused by humidity but does not cover corrosion by atmospheric pollution.~~

~~It is assumed that access to the equipment during installation, maintenance, normal service and decommissioning is restricted to users aware of working procedures necessary to ensure safety.~~

~~This product safety standard takes precedence over general standards for matters of safety.~~

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60050 (all parts), International Electrotechnical Vocabulary (available at <<http://www.electropedia.org>>~~

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60127-1, *Miniature fuses – Part 1: Definitions for miniature fuses and general requirements for miniature fuse-links*

IEC 60255-1, *Measuring relays and protection equipment – Part 1: Common requirements*

~~IEC 60255-21-1, Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section One: Vibration tests (sinusoidal)~~

~~IEC 60255-21-2, Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section Two: Shock and bump tests~~

~~IEC 60255-21-3, Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section 3: Seismic tests~~

IEC 60255-26:2013, *Measuring relays and protection equipment – Part 26: Electromagnetic compatibility requirements*

IEC 60352-1, *Solderless connections – Part 1: Wrapped connections – General requirements, test methods and practical guidance*

IEC 60352-2, *Solderless connections – Part 2: Crimped connections – General requirements, test methods and practical guidance*

IEC 60417, *Graphical symbols for use on equipment*. Available at: <http://www.graphical-symbols.info/equipment>

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

IEC 60664-3:2003, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*
~~Amendment 1:2010~~

IEC TS 60695-2-20, *Fire hazard testing – Part 2-20: Glowing/hot-wire based test methods – Hot-wire coil-ignitability test method – Apparatus, test method and guidance*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60990:1999, *Methods of measurement of touch current and protective conductor current*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*
 IEC 61010-1:2010/AMD1:2016

IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61051-2:2021, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

~~IEC 61140, Protection against electric shock – Common aspects for installation and equipment~~

IEC 61180, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

~~IEC 61180-1:1992, High-voltage test techniques for low-voltage equipment – Part 1: Definitions, test and procedure requirements~~

~~IEC 61180-2, High-voltage test techniques for low-voltage equipment – Part 2: test equipment~~

IEC 61869-6, *Instrument transformers – Part 6: Additional general requirements for low-power instrument transformers*

IEC 61869-10, *Instrument transformers – Part 10: Additional requirements for low-power passive current transformers*

IEC 61869-11, *Instrument transformers – Part 11: Additional requirements for low-power passive voltage transformers*

IEC 62151, *Safety of equipment electrically connected to a telecommunication network*

~~ISO 7000, Graphical symbols for use on equipment – Index and synopsis. Available at: <http://www.graphical-symbols.info/equipment>~~

3 Terms and definitions

~~For the purposes of this document, the terms and definitions given in IEC 60664-1 and IEC 60050-151-448 as well as the following apply.~~

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

accessible conductive part

~~exposed conductive part~~

conductive part of electrical equipment touchable under normal use, ~~which can be touched and which is not normally live, but which can become live when basic insulation fails~~

~~Note 1 to entry: For equipment which is not enclosed, the frame, the fixing devices, etc., may form the accessible conductive parts.~~

~~Note 2 to entry: For equipment which is enclosed, the conductive parts which are accessible when the equipment is mounted in its normal position of use, including those of its fixing surface, form the accessible conductive parts.~~

~~[SOURCE: IEC 60050:1998, 422.01.21, modified – The notes to entry have been added.]~~

3.2

accessible part

part which can be touched under normal ~~conditions~~ use with a standard rigid or jointed test finger as specified in 6.2 of IEC 61010-1:2010 and IEC 61010-1:2010/AMD1:2016

~~Note 1 to entry: A communication circuit/network, which may be connected and taken outside the cubicle housing the equipment, or on the front of the panel without the need to open a cover or flap to access it, should be considered to be accessible, i.e. should it be PEB, PELV, SELV or equivalent.~~

Circuits intended to be connected to an external accessible circuit are considered as accessible conductive parts, for example wired network ports.

~~[SOURCE: IEC 60050:1998, 442.01.15, modified – More details about the test finger and the note to entry has been added.]~~

3.3

adjacent circuit

independent circuit

electric circuit which is separated from the considered circuit by ~~the necessary basic or double/reinforced~~ applicable insulation

~~Note 1 to entry: Circuits which are separated by more than double or reinforced insulation are not considered to be adjacent.~~

3.4

ambient temperature

ambient air temperature

temperature, determined under prescribed conditions, of the air surrounding the complete equipment

Note 1 to entry: For equipment installed inside an enclosure, it is the temperature of the air outside the enclosure.

Note 2 to entry: The ambient temperature is measured at half the distance from any neighbouring equipment, but not more than 300 mm distance from the equipment case, at middle height of the equipment, protected from direct heat radiation from the equipment.

~~[SOURCE: IEC 60050:2000, 441.11.13, modified – "switching device or fuse" has been replaced by "equipment" and a second note to entry has been added. IEC 60050-441:1984, 441-11-13, modified – The preferred term "ambient temperature" has been added. In the definition and Note 1 to entry, "switching device or fuse" has been replaced by "equipment". Note 2 to entry has been added.]~~

3.5

barrier

electrically protective barrier

part providing protection against direct contact from any usual direction of access that is firmly secured in place in such a way that it can only be removed by the use of a tool

~~Note 1 to entry: Barriers may provide protection against the spread of fire (see Clause 7).~~

[SOURCE: IEC 60050-826:2004, 826-12-23, modified – The preferred term "barrier" has been added. At the end of the definition, "that is firmly secured in place in such a way that it can only be removed by the use of a tool" has been added.]

3.6

basic insulation

insulation of hazardous-live-parts to provide basic protection

~~Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.~~

[SOURCE: IEC 60050-826:2004, 826-12-14, modified – ~~the word "which" is replaced by "to"~~ In the definition, "which provides" has been replaced by "to provide" and the Note has been removed.]

3.7

basic protection

protection against electric shock under normal conditions

[SOURCE: IEC 60050-195:2021, 195-06-01]

3.8

bounding surface

outer surface of the equipment case, ~~considered as though metal foil were pressed into contact with accessible surfaces of insulating material~~

3.9

cabinet

free-standing and self-supporting enclosure for housing electrical and/or electronic equipment

Note 1 to entry: A cabinet is usually fitted with doors and/or side panels, which may or may not be removable.

[SOURCE: IEC 60050-581:2008, 581-25-02]

3.10

clearance

shortest distance, measured in air, between two conductive parts, or between a conductive part and the outer bounding surface of the equipment, whether conductive or not

3.12

~~**communication circuit/network**~~

~~circuit/network for receiving and/or transmitting, digital or analogue signals~~

~~Note 1 to entry: It may communicate with other circuits via optical, magnetic or electromagnetic radiation means, or metallic connections.~~

3.11**comparative tracking index****CTI**

numerical value of the maximum voltage in volts which a material can withstand without tracking and without a persistent flame occurring under specified test conditions

[SOURCE: IEC 60050-212:2010, 212-11-59]

3.12**creepage distance**

shortest distance along the surface of a solid insulating material between two conductive parts, or between a conductive part and the bounding surface (accessible part) of the equipment, measured along the surface of insulation

[SOURCE: IEC 60050-151:2001, 151-15-50, modified – The phrase ", or between a conductive part and the bounding surface (accessible part) of the equipment, measured along the surface of insulation" has been added.]

3.13**direct contact**

electric ~~al~~ contact of persons with live parts

[SOURCE: IEC 60050-826:2004, ~~826-03-05~~ 826-12-03, modified – In the definition, the words "or animals" have been omitted.]

3.14**double insulation**

insulation comprising both basic insulation and supplementary insulation

Note 1 to entry: Basic and supplementary insulation are separate, each designed for basic protection against electric shock.

[SOURCE: IEC 60050-195: ~~1998~~ 2021, 195-06-08, modified – The note to entry has been added.]

3.15**enclosure**

housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: Enclosures ~~may~~ can provide protection against the spread of fire (see Clause 7).

[SOURCE: ~~IEC 60050:1998, 195-02-35~~ IEC 60050-151:2001, 151-13-08, modified – Note 1 to entry has been added.]

3.16**extra low voltage****ELV**

voltage not exceeding the maximum value of the prospective touch voltage that is acceptable to be maintained indefinitely under specified conditions of external influences

Note 1 to entry: For the purposes of this document, the ELV values are specified in 4.3.3.2.

SEE: Table A.1

[SOURCE: IEC 60050-195:2021, 195-05-24, modified – The note to entry has been added.]

3.17**fire enclosure**

~~part of the equipment intended to minimize the spread of fire or flames from within~~

enclosure intended as a safeguard against the spread of fire from within the enclosure to outside the enclosure

[SOURCE: IEC 60050-903:2014, 903-04-10, modified – In the definition, the word "protection" has been replaced by "as safeguard", and Note 1 to entry has been deleted.]

3.18

functional earthing earthed circuit

functional grounding grounded circuit, US

~~earthing a point or points in a system or in an installation or in equipment, for purposes other than electrical safety~~

~~[SOURCE: IEC 60050:2004, 826-13-10]~~

circuit that can include PCB tracks, wiring, components and equipotential bonds that is connected to earth for purposes other than electrical safety

Note 1 to entry: Purposes other than electrical safety include screening and reference point for measurements.

3.19

functional insulation

insulation between conductive parts, necessary for the proper functioning of the equipment

[SOURCE: IEC 60050-195:1998, 195-02-41]

3.25

HB40 class material

~~material tested in the thinnest significant thickness used and classified HB40 according to IEC 60695-11-10~~

3.26

HB75 class material

~~material tested in the thinnest significant thickness used and classified HB75 according to IEC 60695-11-10~~

3.20

hazardous energy level

available power level of 240 VA or more, having a duration of 60 s or more, or a stored energy level of 20 J or more (for example, from one or more capacitors), at a potential of 2 V or more

3.21

hazardous live-part

~~live part at a voltage exceeding 33 V a.c. or 70 V d.c.~~

live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-826:2004, 826-12-13]

3.22

hazardous live voltage

HLV

~~normal condition voltage which exceeds 33 V a.c. or 70 V d.c.~~

normal use voltage which exceeds ELV levels

Note 1 to entry: For the purposes of this document the ELV values are specified in 4.3.3.2.

3.23**high-integrity part****high-integrity component**

~~part or component that is considered not to become defective in such a manner as to cause a risk of hazard within the sense of this standard and not subject to failure when a single fault condition is applied~~

part or component whose specification or qualification is well in excess of the application such that the risk of failure is minimal

3.28**limited-energy circuit**

~~circuit that meets all the criteria given in 7.12 of this standard~~

3.24**live part**

~~conductor or~~ conductive part intended to be energized under normal operating conditions, including the neutral conductor

~~Note 1 to entry: This concept does not necessarily imply a risk of electric shock.~~

[SOURCE: IEC 60050-195:1998/2021, 195-02-19, modified – The last part of the definition "~~but by convention not a PEN conductor or PEM conductor or PEL conductor~~" "and mid-point conductor, but excluding the PEN conductor, PEM conductor and PEL conductor" has been omitted.]

3.25**low-power instrument transformer 2****LPIT**

arrangement, consisting of one or more current or voltage transformer(s) which may be connected to transmitting systems and secondary converters, all intended to transmit a low-power analogue or digital output signal to measuring instruments, meters and protective or control devices or similar apparatus

EXAMPLE An arrangement consisting of three current sensors, three voltage sensors connected to one merging unit delivering one digital output is considered an LPIT.

Note 1 to entry: LPITs are commonly called non-conventional instrument transformers (NCIT).

Note 2 to entry: The output power produced by these devices is typically lower than or equal to 1 VA.

[SOURCE: IEC 61869-6:2016, 3.1.601]

3.26**low-power current transformer****LPCT**

low-power instrument transformer for current measurement

[SOURCE: IEC 61869-6:2016, 3.1.602]

3.27**low-power voltage transformer****LPVT**

low-power instrument transformer for voltage measurement

[SOURCE: IEC 61869-6:2016, 3.1.603]

3.30

~~maintenance operative~~

~~operative having appropriate technical training and experience necessary to be aware of hazards to which that operative may be exposed in performing installation/maintenance and of measures to minimize the risks to that person or other persons~~

3.28

maintenance use

state of the equipment when being serviced by trained personnel with any tool removable covers and protective measures removed

3.31

~~micro-environment~~

~~ambient conditions which immediately surround the clearance and creepage distance under consideration~~

~~Note 1 to entry: The micro-environment of the creepage distance or clearance and not the environment of the equipment determine the effect on the insulation.~~

~~[SOURCE: IEC 60050:1998, 442.01.29, modified — The latter part of the definition "excluding self-produced pollution resulting from normal operation of the accessory" has been omitted.]~~

3.29

non-primary circuit

circuit electrically isolated from the AC or DC supply and from external voltage transformers and current transformers

3.33

normal conditions

~~equipment installed and operated under the normal operating conditions for the specified equipment as defined by the manufacturer (excluding maintenance)~~

3.30

normal use

state of the equipment when installed and operated for its intended purpose, with any tool removable covers and protective measures in place

3.31

overheating

operating at a level such that the ~~equipment's~~ thermal limit is exceeded

3.32

overvoltage category

~~number~~ numeral defining a transient overvoltage condition

Note 1 to entry: Overvoltage categories I, II, III and IV are used, see IEC 60664-1.

~~Note 2 to entry: See Clause A.1 for overvoltage category details.~~

[SOURCE: IEC 60050-426:2020, 426-04-48]

3.33

protective class I equipment

equipment with basic insulation ~~as provision~~ and protective bonding for ~~basic~~ protection against electric shock ~~and protective bonding as provision for fault protection~~, such that conductive parts on the outside of the equipment case cannot become live (in the event of a failure of the basic insulation)

3.34**protective class II equipment**
equipment with

- basic insulation as provision for basic protection against electric shock, and supplementary insulation as provision for fault protection; or
- ~~in which basic protection and fault protection are provided by reinforced insulation~~
- double- or reinforced-insulation basic and fault protection

Note 1 to entry: There should be no provision for a protective conductor or reliance upon installation conditions for safety purposes. It is, however, possible to connect an earth conductor to protective Class II equipment for functional (for example, EMC) purposes.

~~[SOURCE: IEC 60050:2008, 851.15.11, modified – The phrase "against electrical shock" and a note to entry have been added while the reference to IEC 61140:2001, 7.3 has been omitted.]~~

3.35**protective class III equipment**

equipment, or parts of equipment, in which protection against electric shock relies upon supply from SELV or PELV circuits and in which hazardous voltages are not generated

3.36**pollution**

~~any~~ addition of foreign matter, solid, liquid or gaseous that can produce a ~~permanent~~ reduction of dielectric strength or surface resistivity of the insulation

[SOURCE: IEC 60050-442:1998, 442-01-28, modified – In the definition, the word "permanent" has been deleted, and the note ~~to entry~~ has been omitted.]

3.37**pollution degree**

number characterizing the expected pollution of the ~~micro-environment~~ ambient conditions which immediately surround the clearance and creepage distance under consideration as detailed in IEC 60664-1

3.40~~**pollution degree 1**~~

~~normally no pollution or only dry, non-conductive pollution occurs.~~

~~Note 1 to entry: Pollution has no influence.~~

3.41~~**pollution degree 2**~~

~~normally only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected~~

3.42~~**pollution degree 3**~~

~~normally conductive pollution, or dry non-conductive pollution occurs, which becomes conductive, due to condensation which is to be expected~~

3.43~~**pollution degree 4**~~

~~normally the pollution generates persistent conductivity caused by conductive dust or by rain or snow~~

3.38

primary circuit

circuit electrically connected ~~direct~~ to the AC or DC supply input and external voltage transformers and current transformers

~~Note 1 to entry: Equipment circuits connected to VTs (voltage transformers) or CTs (current transformers) are also classed as primary circuits.~~

~~Note 2 to entry: Measuring relay circuits supplied from an external a.c. or d.c. power supply, complying with ELV circuit requirements, as in Table A.1, may be treated as non-primary circuits, providing that any transients or impulse voltages on the supply output do not exceed the requirements of Figure 2 of IEC 61010-1:2010.~~

3.39

protective bonding

electrical connection of accessible conductive parts or of protective screening to provide electrical continuity by means of connection to an external protective conductor which is securely returned to earth

3.40

protective bonding resistance

~~impedance~~ resistance between the protective conductor terminal and a conductive part required to be connected to the protective conductor

3.41

protective conductor

conductor provided for purposes of electrical safety, ~~for example, protection against electric shock, by electrically connecting main earthing terminal, or accessible conductive parts, or earth electrode, or earthed point of the source or artificial neutral~~

[SOURCE: IEC 60050-195:1998/2021, 195-02-09, modified – "~~by electrically connecting main earthing terminal, or accessible conductive parts, or earth electrode, or earthed point of the source or artificial neutral~~" has been added.]

3.42

protective earthing

protective grounding, US

earthing ~~of a point in equipment~~ for purposes of protection against electric shock ~~in case of a fault~~

[SOURCE: IEC 60050-195:2021, 195-01-11, modified – The term "electrical safety" has been replaced by "protection against electric shock".]

3.43

protective equipotential bonding circuit

PEB circuit

circuit with a low impedance path from exposed-conductive-parts to extraneous-conductive-parts, to ensure equal potential throughout thus preventing a hazardous potential difference occurring between such parts in the event of a fault

Note 1 to entry: See Table A.1.

3.44

protective extra low voltage circuit

PELV circuit

circuit in which the voltage cannot exceed the value of extra low voltage under normal conditions and under single fault conditions (except earth faults in other electric circuits)

Note 1 to entry: See Table A.1.

3.45

protective impedance

impedance connected between live parts and accessible conductive parts, of such value that the current, under normal ~~conditions~~ use and under likely fault conditions in the equipment, is limited to a safe value, and which is so constructed that the reliability is maintained throughout the life of the equipment

~~Note 1 to entry: A protective impedance should withstand the dielectric voltage withstand test for double insulation, and its choice should take account of its predominated failure mode.~~

[SOURCE: IEC 60050-442:1998, 442-04-24, modified – In the definition, the term "exposed" has been replaced by "accessible", "in normal use" has been replaced by "under normal use", "electronic switch" has been replaced by "equipment" ~~and a note to entry has been added~~.]

3.46

protective screening

protective shielding, US

separation of electric circuits and/or conductors from hazardous-live-parts by an electrically protective screen connected to the protective earth ~~equipotential bonding system and intended to provide protection against electric shock~~

[SOURCE: IEC 60050-195:1998/2021, 195-06-18, modified – In the definition, the words "equipotential bonding system and intended to provide protection against electric shock" have been replaced by "earth".]

3.47

protective separation

separation of one electric circuit from another by means of ~~double insulation, or basic insulation and electrically protective screening, or reinforced insulation~~ basic protection and fault protection

[SOURCE: IEC 60050-195:2021, 195-06-19]

3.48

rated impulse voltage

impulse voltage value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against transient overvoltages and to which clearances are referred

3.49

rated insulation voltage

RIV

voltage value assigned by the manufacturer to the equipment, or to a part of it, characterizing the specified (long-term) withstand capability of its insulation and to which dielectric voltage tests and creepage distances are referred

Note 1 to entry: The rated insulation voltage is not necessarily equal to the rated voltage of equipment which is primarily related to functional performance.

~~Note 2 to entry: The rated insulation voltage refers to the insulation between electric circuits.~~

~~Note 3 to entry: For clearances and solid insulation the peak value of the voltage occurring across the insulation or clearance is the determining value for the rated insulation voltage. For creepage distances, the r.m.s. or d.c. value is the determining value.~~

3.50

rated voltage

value of voltage assigned by the manufacturer, ~~for a specified~~ over the normal operating condition of a component, device or equipment

Note 1 to entry: Equipment may have more than one rated voltage value or may have a rated voltage range.

[SOURCE: IEC 60050-442:2014, 442-09-10, modified – In the definition, the term "rated value" has been replaced by "value", the term "to" has been replaced by "over the normal operating condition of", and at the end of the definition the words "and to which operation and performance characteristics are referred" and Note 2 to entry have been omitted.]

3.51

reinforced insulation

insulation ~~of hazardous live parts~~ that provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: Reinforced insulation ~~may~~ can comprise several layers that cannot be tested singly as basic insulation or supplementary insulation.

[SOURCE: IEC 60050-195: ~~1998~~2021, 195-06-09]

3.52

restricted access area

area accessible only to ~~electrically skilled persons and electrically instructed persons~~ users with the proper authorization and knowledge of any safety hazards

~~Note 1 to entry: These areas include closed switch plants, distribution plants, switchgear cells, transformer cells, distribution systems in metal sheet enclosures or in other closed installations.~~

[SOURCE: IEC 60050-195: ~~1998~~2021, 195-04-04, modified – ~~"and knowledge of any safety hazards" and a note to entry~~ In the definition, the words "electrically skilled persons and electrically instructed persons" have been replaced by "users" and the words "and knowledge of any safety hazards" have been added.]

3.53

routine test

conformity test made on each individual ~~item~~ equipment during or after manufacture

Note 1 to entry: Individual equipment includes complete products and spare parts.

[SOURCE: IEC 60050-151:2001, 151-16-17, modified – In the definition, the word "item" has been replaced by the word "equipment", and Note 1 to entry has been added.]

3.54

safety critical component

component which is relied upon for the integrity of its electrical insulation, mechanical strength, thermal, or flame-retardant properties during normal operation and single fault conditions, to prevent ~~the risk of electric shock, injury, or fire~~ a safety hazard

3.55

safety extra low voltage circuit

separated extra low voltage circuit

SELV circuit

~~SEE: Table A.1~~

circuit in which the voltage cannot exceed the value of extra low voltage under normal conditions and under single fault conditions (including earth faults in other electric circuits)

3.56

screen

shield, US

conductive part that encloses or separates electric circuits and/or conductors

Note 1 to entry: See Table A.1.

3.57**single fault condition**

condition in which ~~one fault is present which could cause a hazard~~ there is a fault of a single protection (but not a reinforced protection) or of a single component or a device

Note 1 to entry: If a single fault condition results ~~unavoidably in another fault condition, the two failures are considered as one single fault~~ in one or more other fault conditions, all are considered as one single fault condition.

[SOURCE: IEC 60050-903:2013, 903-01-15]

3.58**solid insulation**

material that provides electrical insulation between two opposite surfaces, not along an outer surface

3.59**supplementary insulation**

independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation

[SOURCE: IEC 60050-195:1998/2021, 195-06-07, modified — "~~for fault protection~~" , that provides fault protection" has been replaced by "in order to provide protection against electric shock in the event of a failure of basic insulation".]

3.60**tracking**

progressive formation of conductive paths, which are produced on the surface or within a solid insulating material, due to the combined effects of electric stress and electrolytic contamination

Note 1 to entry: Tracking usually occurs due to surface contamination.

[SOURCE: IEC 60050-212:2010, 212-11-56]

3.61**type test**

test of one or more devices made to a given design, to check if these devices comply with the requirements of the standard concerned

[SOURCE: IEC 60050-851:2008, 851-12-05]

3.62**user**

person ~~not~~ with the appropriate training and experience necessary to be aware of hazards to which they are exposed when ~~operating~~ accessing the equipment in a restricted access area and aware of measures to minimize ~~the danger~~ a hazardous situation to themselves and other persons

~~Note 1 to entry: User can be classified as an operator accessing the equipment for routine purposes (considered to have access to the front of the unit only).~~

3.63**wired network port 3**

port for the connection of voice, data and signalling transfers intended to interconnect widely dispersed systems by direct connection to a single-user or multi-user communication network

Note 1 to entry: Examples of these include CATV, PSTN, ISDN, xDSL, LAN and similar networks.

Note 2 to entry: These ports may support screened or unscreened cables and may also carry AC or DC power (e.g. PoE) where this is an integral part of the telecommunication specification.

Note 3 to entry: A port generally intended for interconnection of components of a system under test (e.g. EIA-232, IEEE Standard 1284 (parallel printer), Universal Serial Bus (USB), IEEE Standard 1394 ("Fire Wire"), etc.) and used in accordance with its functional specifications (e.g. for the maximum length of cable connected to it), is not considered to be a wired network port.

Note 4 to entry: Optical fibre interfaces are considered as a wired network port. To achieve maximum power dissipation, it is important that the optical fibre ports are active when required during the safety assessment (during temperature rise testing, etc.)

3.64 withstand

~~state of survival~~ ability of the equipment not to ~~be damaged~~ be damaged when imposed environmental or test conditions are applied (for example, impulse voltage)

3.65 working voltage

highest RMS value of the AC or DC voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

Note 1 to entry: Transients are disregarded.

Note 2 to entry: Both open-circuit conditions and normal operating conditions are taken into account.

[SOURCE: IEC 60050-581:2008, 581-21-19, modified – Notes 1 and 2 to entry have been added.]

~~4 General safety requirements~~

~~4.1 General~~

~~The equipment shall not jeopardize the safety of people and property.~~

~~Protection against electric shock for class I, II or III equipment is applicable to those parts accessible under normal conditions.~~

~~ELV, PEB, PELV and SELV circuits provide protection from electric shock by hazardous live voltages, and are not necessarily related to class I, II or III equipment class.~~

~~4.2 Earthing requirements~~

~~Earthing in equipment may be required not only to reduce the effects of interference, but also, and more importantly, for reasons of personnel safety. Where there is any conflict between these two requirements, personnel safety shall always take precedence.~~

4 Protection against electric shock

5.1 General

5.1.1 Introductory remark

~~Users shall be protected against electric shock hazards by use of good constructional and engineering practice.~~

~~The testing of components and equipment with regard to protection against electric shock shall be conducted as type tests and routine tests as defined in Clause 10.~~

~~Protection against contact with accessible hazardous live parts shall be provided.~~

~~Any conductive part that is not separated from the hazardous live parts by at least basic insulation shall be considered to be a live part.~~

~~A metallic accessible part is considered to be conductive if its surface is bare or is covered by an insulating layer which does not comply with the requirements of basic insulation.~~

~~A single-fault condition applied to the equipment shall not cause an electric shock hazard.~~

~~Unearthed accessible conductive parts which may become hazardous live under a single-fault condition shall be separated from hazardous live parts by double or reinforced insulation or be connected to the protective conductor or meet the requirements of 5.1 to 5.1.11.~~

~~Annex A covers equipment isolation class.~~

~~Annex C is for the determination of clearance and creepage distance and withstand type test voltages.~~

4.1 Protection from contact with hazardous-live-parts

4.1.1 General

Protection against direct contact with ~~accessible~~ hazardous-live-parts shall be provided by adequate insulation, the equipment case or a barrier. Access to the equipment during installation, maintenance use, normal use and decommissioning shall be restricted to users aware of working procedures necessary to ensure safety. **4**

The testing of components and equipment with regard to protection against electric shock shall be conducted as type tests and routine tests as defined in Clause 9.

Unearthed accessible conductive parts which can become hazardous live under a single fault condition shall meet the requirements of 4.1 to 4.10.

4.1.2 Insulation

Any conductive part that is not separated from the hazardous-live-parts by at least basic insulation shall be considered a live part. The insulation requirements shall be determined after consideration of the following influencing factors:

- rated insulation voltage of the circuit under consideration (see ~~6.7 of IEC 61010-1:2010 C.1.3~~);
- overvoltage category (see Annex B and Annex C);
- pollution degree (see Annex C);
- isolation ~~level~~ class, for example, ELV, SELV, PELV, or PEB (see Annex A).
- ~~insulation prescription (see Annex A and Annex C).~~

4.1.3 ~~Equipment case~~ enclosure and barriers

~~Hazardous live parts shall be located within the equipment case or behind barriers that meet at least the requirements of the protective type IP2X (finger protection) according to 5.1 of IEC 60529:1989, Amendment 1:1999 such that they are not accessible under normal conditions. If a cover is removed without the use of a tool then warning symbol 12 from Table 10 shall then be visible.~~

~~The top surfaces of barriers that are accessible in normal use shall meet at least the requirements of the protective type IP4X (protection against 1mm diameter wire) according to 5.1 of IEC 60529:1989, Amendment 1:1999. Any such barriers shall have sufficient mechanical strength, stability and durability to maintain the specified degree of protection and be firmly secured in place in such a way that it may only be removed by the use of a tool.~~

~~Hazardous live parts which may be accidentally touched by a maintenance operative when manually changing settings etc., shall meet at least the requirements of protective type IP2X according to 5.1 of IEC 60529:1989, Amendment 1:1999.~~

~~Compliance with 5.1.2.3 is checked using a test finger as specified in 6.2 of IEC 61010-1:2010.~~

The enclosure protection required by the product depends upon face and access level; minimum equipment enclosure requirements are detailed in Table 1.

Table 1 – Equipment enclosure requirements for protection against electric shock 5

Face	IP Code (IEC 60529:1989, IEC 60529:1989/AMD1:1999, IEC 60529:1989/AMD2:2013)	Requirements
Front panel, sides	IP2X or IPXXB	Hazardous-live-parts shall be located within the equipment enclosure or behind barriers such that they are not accessible under normal use. If a cover can be removed without the use of a tool, warning symbol 12 from Table 12 shall be visible.
Front panel connection(s)	IP2X	The front panel connections and terminal wiring, which are ELV, shall be accessible under normal use.
Top	IP4X	The top surfaces of barriers that are accessible in normal use shall provide ingress protection against falling objects, loose wires, washers, etc. Any such barriers shall have sufficient mechanical strength, stability and durability to maintain the specified degree of protection.
Bottom	IP4X	The bottom surfaces of barriers that are accessible in normal use shall provide ingress protection against loose wires, etc. Any such barriers shall have sufficient mechanical strength, stability and durability to maintain the specified degree of protection.
Rear	IP2X	Hazardous-live-parts shall be located within the equipment enclosure or behind barriers such that they are not accessible under normal use.
Rear panel connection(s)	IP1X	The rear connection panel, terminal wiring, under normal use shall be in a restricted access area and shall be IP1X or greater.
Corners		The corner shall have the highest IP taken from the adjacent sides.

Further requirements for accessible parts are detailed in 4.3.2.

Conformity with 4.1.3 is checked by applying the safety ingress requirements of IEC 60529:1989, IEC 60529:1989/AMD1:1999, and IEC 60529:1989/AMD2:2013.

4.1.4 Hazardous live terminations using stranded wire

The end of a stranded wire shall not be consolidated by soft soldering at places where the wire is subject to contact pressure, unless the method of clamping is designed so as to reduce the likelihood of a bad contact due to cold flow of the solder. Spring terminals that compensate for the cold flow are deemed to satisfy this requirement. Preventing the clamping screws from rotating is not considered to be adequate.

Terminals shall be located, guarded or insulated so that, should a strand of a flexible wire escape when the wire is fitted, there is no likelihood of accidental contact between such a strand and:

- accessible conductive parts; or

- unearthed conductive parts separated from accessible conductive parts by supplementary insulation only.

A loose strand of 8 mm ~~nominal~~ length is normally considered for assessing this risk.

If the manufacturer determines that there is a risk, a recommendation shall be given in the documentation and a warning symbol 14 from Table 12 marked on the equipment. The risk can be eliminated, for example, by the use of an insulated crimp terminal or a single-strand wire.

~~Compliance~~ Conformity with 4.1.4 is checked by inspection.

5.1.3 ~~Discharge of capacitors~~

~~After switching off the equipment, capacitors shall be discharged within 5 s to a residual charge of 50 μ C or to a voltage of 20 V. In the case of installed equipment, where the voltage at the plug and socket devices can be touched and these devices may be pulled out when live, without the use of tools, the capacitors shall be discharged within 1 s to a charge of 50 μ C, or to a voltage of 20 V.~~

~~With respect to the above two discharge cases, testing shall be by calculation of the energy, or measurement of the voltage, 5 s or 1 s after switching off the equipment. Where several capacitors are interconnected throughout the circuit, this shall be allowed for, in such calculations.~~

~~If the above parameters cannot be complied with, due to design constraints, there shall be an easily observable warning on the equipment that such capacitors should be safely discharged during decommissioning.~~

~~Compliance with 5.1.3 is checked by calculation or measurement.~~

4.2 Protective impedance

A protective impedance shall limit the current or voltage to the levels of 4.3.3.2 in normal use and 4.10.4.1.2 in single fault condition.

Insulation between the terminations of the protective impedance shall meet the requirements of double insulation or reinforced insulation.

A protective impedance shall be one or more of the following ~~so that unearthed accessible conductive parts cannot become hazardous live as a result of a single-fault condition.~~

- a) An appropriate ~~high-integrity~~ single component which shall be constructed, selected and tested so that safety and reliability for protection against electric shock are assured.

~~Examples are high-voltage withstand capacitors and resistors rated at a minimum of 3 250 V r.m.s. for at least 1 min and shall meet the requirements of 5.1.5.3.2 under the normal conditions and 5.2.4.1.2 under a single-fault condition. The power rating, at maximum ambient temperature, of a high-integrity resistor, shall be at least twice that of the resistor dissipation, under normal use. If the predominant failure mode of the component is short circuit, then a single component shall not be used.~~

In particular, the component shall be:

- 1) rated for twice the maximum working voltage;
 - 2) if a resistor, rated for twice the power dissipation for the maximum working voltage;
- b) a combination of components, for example, two Y rated capacitors in series, each rated for the total working voltage across the pair. Each capacitor shall have the same ~~nominal~~ rated capacitance value and a withstand voltage rating of at least 2 000 V RMS, 1 min. This provides basic protection against electric shock in the case of a single fault condition.

- ~~A combination of basic insulation and a current or voltage limiting device.~~

~~Compliance~~ Conformity with protective impedance can be demonstrated by application of the appropriate voltage test for double ~~/ or~~ reinforced insulation in Table C.8 to Table C.11 for a test site altitude of up to 2 000 m. For test site altitudes ~~other than~~ over 2 000 m, the test voltage should be adjusted in accordance with Table C.12.

Components, wires and connections shall be rated in accordance with the requirements for both normal ~~conditions~~ use and appropriate single fault conditions. It is permissible for double insulation or reinforced insulation to be bridged by components meeting the requirement for protective impedance. ~~Compliance~~ Conformity of components with 4.2 and any associated basic insulation shall be checked after a single fault condition assessment or test according to 9.6.5.5. Any associated basic insulation shall be checked by assessment, measurement or testing in accordance with Annex C ~~of this standard and 6.7 of IEC 61010-1:2010~~.

4.3 Accessible parts

4.3.1 General

Unless obvious, determination of whether a part is accessible, under normal use, shall be made as specified below and in 4.3.2.

Circuits intended to be connected to an external accessible circuit shall be considered as accessible conductive parts, for example ~~communication circuits~~ wired network port.

Appropriate test fingers, as specified in 4.3.2.2, shall be applied without force unless a force is specified. Parts are considered to be accessible if they can be touched with a finger or pin, or if the covering does not provide suitable protection when touched under normal use (see below).

Where accessible conductive parts or circuits are separated from other parts by double insulation or reinforced insulation that is bridged by components in accordance with 4.2, the accessible parts or circuits shall comply with current limits in 4.3.3.2 for the normal ~~condition~~ use and 4.10.4.1.2 for a single fault condition. These requirements shall apply after dielectric voltage testing.

For hazardous-live-parts, a part is considered to be accessible if the test finger or pin reaches a point nearer to the hazardous-live-part than the applicable clearance for basic insulation at the ~~working~~ rated impulse voltage determined from IEC 60664-1.

For equipment accepting plug-in modules, parts are considered to be accessible if they can be touched with the jointed test finger (see 4.3.2.2) up to a depth of 180 mm from the opening in the equipment.

Materials which can easily be damaged are not considered to provide suitable insulation (for example, lacquer, enamel, oxides and anodic films). Non-impregnated hygroscopic materials, such as paper, fibres and fibrous material, are also not considered to provide suitable insulation.

A metallic accessible part is considered to be conductive if its surface is bare or is covered by an insulating layer which does not comply with the requirements of basic insulation.

4.3.2 Determination of accessible parts

4.3.2.1 General

If the user is intended to perform any actions in normal use, with or without the aid of a tool (a screwdriver, a coin, a key, etc.), which will increase the accessibility of parts, such actions shall be taken before performing the examinations of 4.3.2.2 to 4.3.2.3. Examples include:

- removing covers;
- adjusting controls;

- replacing consumable material;
- removing parts.

4.3.2.2 General examination

The jointed test finger (see IEC 61032 and IEC 60529:1989) shall be applied in every possible position. Where a part could become accessible by applying a force, the rigid test finger (see 6.2 of IEC 61010-1:2010 and of IEC 61010-1:2010/AMD1:2016) shall be applied with a force of 10 N. The force shall be exerted by the tip of the test finger so as to avoid wedge and lever action. The test shall be applied to all outer surfaces, including the bottom.

~~5.1.5.2.3 Openings above parts, enclosed by the case, which are hazardous live~~

~~A metal test pin 100 mm long and 4 mm in diameter shall be inserted in all openings in the equipment case, above parts (the test pin shall be freely suspended) which are hazardous live. The test pin shall penetrate up to 100 mm. This test shall not be applied to terminals.~~ **6**

4.3.2.3 Openings for pre-set controls

A metal test pin 3 mm in diameter (force applied 10 N) shall be inserted through holes, in the equipment case, intended to give access to pre-set controls which require the use of a screwdriver or other tool. The test pin shall be applied in every possible direction through the hole; additional information can be found in IEC 61010-1. Penetration shall not exceed three times the distance from the equipment case surface to the control shaft or 100 mm, whichever is smaller.

4.3.2.4 ELV rated or live parts accessible when cover removed

If ELV rated or live parts, such as replaceable batteries or electromechanical relay contacts, are accessible when the cover is removed without the aid of a tool, then a warning label is required, visible when the cover is removed. This warning shall comprise symbol 14 and/or symbol 12 in Table 12.

4.3.2.5 Wiring terminals

Wiring terminals which are accessible under normal use, for example terminals on the front of a product, shall meet the requirement of Table 1.

Wiring terminals which are behind a panel, or in a restricted access area, and cannot be touched in normal use shall be deemed non-accessible. However, a protection of at least type IP1X according to 5.1 of IEC 60529:1989, ~~Amendment 1:1999 should~~ shall be provided to prevent electric shock due to accidental contact.

~~If at least a~~ the protection is of type IP0X or IP1X, according to 5.1 of IEC 60529:1989, ~~Amendment 1:1999, is not provided~~ then the warning symbol 12 in Table 12 shall be used in the vicinity of accessible hazardous live wiring terminals.

~~Compliance~~ Conformity with 4.3.1 to 4.3.2.5 shall be demonstrated by ~~visual inspection or~~ test.

4.3.3 Permissible limits for accessible parts

4.3.3.1 General

The voltage, current, charge or energy between an accessible part and reference test earth, or between any two accessible parts on the same piece of equipment ~~within a distance of 1,8 m~~ (over a surface or through air), shall not exceed the values of 4.3.3.2 in normal ~~condition~~ use, nor those of 4.10.4.1.2 in single fault condition.

4.3.3.2 Values under normal-conditions use

Values under normal-conditions use are listed below. ~~Values exceeding the levels/limits of items a) to c) below, in normal conditions, are deemed to be hazardous live. The limits of items b) and c) below apply only if the voltage exceeds the values of item a).~~ Voltages above the levels of a) are deemed to be hazardous live if any of the levels of b) or c) are exceeded at the same time.

a) Voltage levels: ~~33 V a.c. or 70 V d.c.~~ 30 V AC RMS or 60 V DC **7**

For equipment rated for use in wet locations (either device or operator or both in wet locations due to rain, condensation, etc.), the voltage levels are ~~25 V a.c. or 37,5 V d.c.~~ 16 V AC RMS or 35 V DC.

b) Current levels under normal-conditions use: indicated in Table 2.

Table 2 – Current levels under normal-conditions use

Installation location	Figure 3 ~~or~~ Figure 4 of IEC 60990:1999 2016 Measurement circuit to be used	Sinusoidal waveforms	Non-sinusoidal or mixed frequency waveforms	
		mA RMS	mA peak	mA DC
Dry	Figure 4	0,5	0,7	2
Wet	Figure 3 with $R_S = 375 \Omega$ (instead of 1 500 Ω)	0,5	0,7	2
Dry	Figure 3 with $R_B = 75 \Omega$ Relates to possible burns in the frequency range 30 kHz to 500 kHz	70	-----	-----

c) ~~Charge or energy of capacitance levels under normal conditions: indicated in Table 2.~~

After switching off the equipment, capacitors shall be discharged within 5 s to a residual charge in Table 3 or to a voltage of 20 V or less. In the case of installed equipment, where the voltage at the plug-and-socket devices can be touched and these devices can be pulled out when live, without the use of tools, the capacitors shall be discharged within 1 s.

With respect to the above two discharge cases, verification shall be by calculation of the energy in the total in-circuit capacitance, or measurement of the voltage, 5 s or 1 s after switching off the equipment.

If the above parameters cannot be complied with, due to design constraints, there shall be an easily observable warning on the equipment that such capacitors should be safely discharged during decommissioning (symbol 14 from Table 12).

Table 3 – Charge or energy of capacitance levels under normal-conditions use

Maximum level	For peak or DC voltages
45 μC	Up to 15 kV
350 mJ	$\geq 15 \text{ kV}$
NOTE Figure 3 of IEC 61010-1:2010 shows the maximum acceptable voltage for the capacitance value for both normal use and single fault condition.	

4.4 ~~Bonding to the protective conductor~~ Earthing and protective bonding requirements

4.4.1 General

Earthing in equipment may be required for reasons of personnel safety or to reduce the effects of electromagnetic interference. Where there is any conflict between these two requirements, personnel safety shall always take precedence. The acceptable arrangement of protective means against electric shock is illustrated in Figure 4 of IEC 61010-1:2010.

4.4.2 Insulation between live parts and accessible conductive parts

Accessible conductive parts shall be bonded to the protective earth conductor terminal if they could become hazardous live in the case of a single fault of the primary protective means specified in 4.1. Alternatively, such accessible parts shall be separated from parts which are hazardous live by a conductive protective screen or barrier bonded to the protective earth conductor terminal. For measuring and ~~test~~ protection equipment, indirect bonding is permitted as an alternative to direct bonding.

Unearthed accessible conductive parts such as equipment doors or flaps, handles, etc. ~~shall meet one of the following criteria~~ need not be bonded to the protective earth conductor if they are separated from all hazardous-live-parts by double insulation or reinforced insulation.

~~Unearthed accessible conductive parts need not be bonded to the protective conductor if they are separated from all hazardous-live-parts by double insulation or reinforced insulation.~~

Equipment of protective class I ~~protection~~ shall have a minimum of basic insulation between the ~~unearthed~~ accessible conductive parts bonded to protective earth conductor and live parts, provided that the insulation cannot be reduced to less than basic insulation by any single fault including mechanical impact, loose wires and terminals, etc. Mechanical retention can be used to ensure maintenance of basic insulation under a single fault condition. Screws or nuts with lock washers are not regarded as liable to become loose, nor are wires which are mechanically secured by more than soldering alone.

Verification ~~of clearance~~ shall be made by measurement, where there is any doubt of ~~compliance~~ conformity.

4.4.3 Protective bonding

4.4.3.1 General

Accessible conductive parts shall be bonded to the protective conductor; it is not, however, essential when one of the following applies.

- ~~When~~ Unearthed accessible conductive parts are exclusively related to electrical circuits with ~~protection~~ automatic disconnection of supply, or with current or voltage limiting in case of direct contact according to 4.3, and the voltage does not exceed ELV limits (see Annex A).
- ~~When magnetic cores are used, for example transformers, chokes and contactors.~~
- The unearthed accessible conductive parts are of small dimensions, in normal use are not intended to be grasped, have a low probability of contact, and are separated from hazardous-live-parts by at least basic insulation.

Additional information for the acceptable arrangement of protective bonding against electric shock can be found in IEC 61010-1:2010, Figure 4.

4.4.3.2 Bonding of parts connected to the protective conductor

The equipment design ~~should~~ shall ensure that any painting or coating of surfaces within the protective earth bonding circuit ~~shall~~ does not affect the protective bonding resistance of that circuit.

See 9.6.4.5 for protective bonding test requirements.

4.4.3.3 Protection against corrosion

Conductive parts in contact at protective earthing terminals and connections shall ~~not be subject~~ chosen to ~~significant~~ minimize electro-chemical corrosion ~~due to electrochemical action~~ between materials in any working, storage or transport environment conditions as specified in the instructions supplied with the equipment.

Corrosion resistance can be achieved by a suitable plating or coating process.

~~Compliance with 5.1.6.4 is checked by determination of the electrochemical potential difference between the dissimilar metals, also by inspection after the normally-conducted damp-heat type test.~~

Conformity with 4.4.3.3 is tested by applying the conducted damp-heat, steady state type test (including protective bonding test requirements given in 9.6.4.5).

4.4.3.4 Interruption of protective bonding

Where the protective ~~connection~~ bonding to a subassembly of equipment is made by a plug-and-socket device when it is live or conducting, the protective ~~connection~~ bonding shall not be broken before the live conductors. On re-connection, the protective ~~conductor~~ bonding shall re-connect before the live ~~connection~~ conductors or, at the latest, together with the live conductors.

Conformity is checked by inspection and/or test.

4.5 Functional ~~earthing~~ earthed circuits

If functional earthing of accessible ~~or other conductive~~ parts is necessary, the following apply.

- It is permitted to connect the functional ~~earthing~~ earthed circuit to a protective conductor terminal or to a protective bonding conductor.
- The functional ~~(or protective) earthing~~ earthed circuit shall be separated from ELV, ~~PEB, PELV and SELV~~ circuits by at least ~~functional~~ basic insulation.
- The functional ~~earthing~~ earthed circuit shall be separated from PEB and PELV circuits by at least functional insulation.
- The functional earthed circuit shall be separated from parts at hazardous voltage in the equipment by either:
 - double insulation or reinforced insulation; or
 - a protectively earthed screen or another protectively earthed conductive part, separated from parts at hazardous voltages by at least basic insulation.

~~Compliance~~ Conformity is checked by inspection, measurement and test.

4.6 Protective conductor connection

Equipment with internal protective bonding shall have means of connection for the external protective conductor, preferably near to the terminals for the respective live conductors.

The protective conductor terminal shall be corrosion-resistant. It shall be capable of accommodating cables of at least the same cross-sectional area as the equipment circuit with the highest current, ~~or~~ protection element rating which ~~may~~ can cause an earth fault.

The means of connection for the protective conductor shall not be used as a part of the mechanical assembly of the equipment.

Conformity is checked by inspection.

4.7 High leakage current

Where equipment has a continuous leakage current of more than 3,5 mA AC RMS or 10 mA DC in normal use, the ~~supply input~~ protective conductor shall be connected as for permanently connected equipment (see Clause E.2); this shall be stated in the equipment documentation.

Any current measurements shall be performed using the measuring circuit in Figure 4 of IEC 60990:1999/2016. The equipment shall be isolated from earth and from the measuring circuit connected between the protective conductor terminal and the protective conductor.

Conformity is checked by measurement.

4.8 Solid insulation

4.8.1 General

Solid insulation shall be designed to resist the ~~stresses which occur, especially~~ mechanical, electrical, thermal, climatic, ~~and other stresses that are to be expected under normal conditions, and it shall have a sufficient resistance to ageing~~ use throughout the life of the equipment.

Solid insulation shall be designed to withstand mechanical vibration or shock which can be expected during transportation, storage and installation ~~and use~~. Conformity with the requirements in 4.8.2 shall be checked after the mechanical tests in 9.6.2.1 and 9.6.2.2.

Wire insulation shall be considered as solid insulation.

Thin, easily damageable materials, such as coating with lacquer or oxides and anode coatings, are considered insufficient to satisfy these requirements.

Conformity with 4.8 is checked by inspection, measurement and test.

4.8.2 Requirements

The maximum temperature of the solid insulation, under normal ~~conditions~~ use at maximum ambient temperature, shall be less than the temperature given for the appropriate class in Table 8 or by 6.10.2.

~~Compliance~~ Conformity of solid insulation shall be verified by performing dielectric voltage and impulse withstand type tests, according to the relevant rated working voltage and overvoltage category, determined from the appropriate Table C.2 to Table C.11, and Table C.12. ~~The term solid insulation refers to material that provides electrical insulation between two opposite surfaces, not along an outer surface. Its required properties are specified either as the actual minimum distance through the insulation, or by other requirements and tests in this standard instead of a minimum distance. The test method shall be performed according to the method detailed in 9.6.4.2 and 9.6.4.3. Any test therefore only~~ The test proves the minimum distance through the insulation, not the creepage distance across the surface of the insulation.

~~Compliance with 5.1.9 is checked by inspection, measurement and test.~~

4.9 Clearances and creepage distances

4.9.1 General

Clearance and creepage distances shall be determined from the appropriate Table C.2 to Table C.11, the clearance and creepage distances can be interpolated for voltages above 300 V. **8**

~~NOTE—The clearance and creepage distances in Table C.1 to Table C.10 can be interpolated for voltages above 300 V.~~

The minimum creepage distance shall not be less than the minimum clearance in air. These clearances and creepage distances are minimum values; manufacturing tolerances shall additionally be taken into account.

Examples for design and measurement of clearances and creepage distances are given in 6.2 of IEC 60664-1:2007-2020.

Inhomogeneous fields generally apply to equipment.

For the functional insulation of pulsating voltage waveforms, the RMS voltage of the waveform shall be calculated and used as the working voltage in the determination of the required clearances and creepage distances. The amplitude of repetitive peak voltages of short duration (defined as being less than 2 % of the waveform cycle duration) should not exceed 175 % of the rated RMS working voltage used to determine the minimum creepage distance.

Where there is any doubt that the required clearance and creepage distances are compliant, measurements shall be made.

If appropriate, type tests and routine testing ~~or sample testing~~ of clearances shall be carried out to determine ~~compliance~~ conformity with 4.9, in accordance with Clause 9.

4.9.2 Clearances

4.9.2.1 General

Clearances are specified to withstand the maximum transient overvoltage that can be present on the circuit, either as a result of an external event (such as a lightning strike, or a switching transient), or as the result of the operation of the equipment. Clearances shall be determined with reference to Annex A and Annex C. For clearances in primary circuits, Table B.1 should also be referred to.

~~The design of The clearance between any two circuits shall conform to the greater clearance of the two.~~

The clearance distance between any two circuits shall be based on the maximum transient overvoltage originating from either circuit.

In order to maintain ~~a fixed withstand test voltage~~ product safety, the clearances for equipment at altitudes greater than 2 000 m shall be multiplied by the factor given in Table 4.

Table 4 – Altitude multiplication factor

Altitude metres	Clearance multiplying factor
2 000	1,00
3 000	1,14
4 000	1,29
5 000	1,48

~~For installations above 2 000 m, refer to Table C.11.~~ For test site altitudes other than 2 000 m, the corresponding correction factors of the test voltage are given in Table C.12. If necessary, take appropriate measures to limit the ~~impulse~~ transient voltages the equipment is subjected to; for example, use of spark gaps or transient suppressors ~~etc.~~

4.9.2.2 Clearances for primary circuits

The clearances in air relating to primary circuits are determined by the rated impulse voltage (refer to C.1.4).

Basic insulation is the minimum requirement between primary circuits and other circuits, (primary or non-primary circuits) including accessible parts and earthed parts. Additional insulation (for example, functional or supplementary insulation) may be required, depending upon the isolation class (see Annex A). ~~To minimize the risk of fire, it is necessary to correctly~~ The design of functional insulation, such as that across a primary circuit, shall be such that the risk of fire is minimized.

~~Where the clearance does not comply with the relevant Table C.3 to Table C.10, this may be proven by testing using a test voltage determined by the multiplication of the withstand voltage, by the appropriate multiplication factor for altitude from Table C.11. The preferred method to prove the product is safe, where the clearance is below the minimum specified value, is to use the a.c. or d.c. value given in the table, rather than the impulse voltage, unless the impulse voltage generator characteristics and impulse voltage amplitude are according to 10.6.4.2.3.~~

The clearance values are stated in Annex C. For rated voltages and installation categories other than those given in Annex C tables, refer to IEC 60664-1:2020, Annex F.

NOTE The withstand voltages in Table C.2 to Table C.11 are for inhomogeneous fields. In many cases, the clearance in air between two parts of the equipment is between inhomogeneous and homogeneous; hence, clearances can be proven by testing.

~~The clearance values are stated in Annex C, for impulse voltages other than those given in Annex C tables refer to IEC 60664-1:2007, Annex A.~~

4.9.2.3 Clearances for non-primary circuits

Clearances for non-primary circuits shall withstand the maximum transient overvoltage that can be present on the circuit. If transient overvoltages cannot occur, clearances are based on the ~~nominal~~ rated working voltage.

The clearance values are stated in Annex C. For impulse or working voltages other than those given in Annex C tables, refer to Annex A of IEC 60664-1:2007/2020.

4.9.3 Creepage distances

~~It shall be~~ is assumed that the equipment within the scope of this document is subject to continuous voltage stress over a long period, requiring the design of appropriate creepage distances.

Creepage distances shall be determined with reference to Annex A and Annex C.

Examples for design and measurement of creepage distances are given in 5.2 and 6.2 of IEC 60664-1:2007/2020.

~~The design of creepage distance between any two circuits shall conform to the greater creepage distance of the two.~~

The creepage distance between any two circuits shall be based on the maximum working voltage across this creepage distance (typically sum of the voltages from these circuits).

If pollution degree 3 or 4 causes persistent conductivity, for example, due to carbon or metal dust, the dimensions for creepage distances cannot be specified. Instead, the surface of insulation ~~has to~~ shall be designed to avoid a continuous path of conductive pollution (for example, by means of ribs or grooves, as determined by 5.2.5 of IEC 60664-1:2007/2020).

Table C.13 indicates additional protection which may be used to reduce the pollution degree within the equipment. If Table C.13 is used to determine reduced creepage distance, it should be ensured that this is not less than the minimum allowed clearance.

~~Compliance~~ **Conformity** of creepage distances with 4.9.3 shall be verified by measurement in the case of doubt. It cannot be verified by voltage withstand testing.

Interpolation of creepage distances in Annex C tables is permitted, for both primary and non-primary circuits.

4.10 Single fault conditions

4.10.1 Testing in single fault condition

The equipment shall not present a risk of electric shock or fire after a single fault test. ~~It is not required that a single fault condition is applied to double or reinforced insulation~~ **9**. ~~It does not have to need not be functional after the test.~~

The following requirements apply.

- The fault conditions which are liable to result in electric shock or fire hazards, as generally evidenced by examination of the equipment and its circuit diagram, shall be applied.
- Fault tests shall be made except where it can be demonstrated that it is improbable that a hazard will arise from a particular single fault condition.
- The equipment shall be operated under the least favourable combination of reference test conditions.

These conditions include worst-case tolerance of rated voltage and current, worst-case equipment orientation, whether covers or other removable parts ~~may are not be~~ fitted during normal ~~conditions use~~, maximum specified external fuse rating.

NOTE Small parts, such as screws and rivets which are not accessible and are isolated from HLV circuits by at least basic insulation, are not taken into consideration.

Subclause 6.10 provides an alternative to testing for protection against spread of fire under a single fault condition but is not applicable to electric shock hazards.

4.10.2 Application of single fault condition

4.10.2.1 General

Single fault conditions shall be applied one at a time and shall be applied in turn in the most convenient order. Multiple simultaneous faults shall not be applied; they ~~may can~~, however, result from the application of a single fault. The application of a single fault ~~may can~~ result in the equipment being in a hazardous state and the test personnel should take appropriate precautions such as ~~the use of safety screens, etc.~~

After the application of a single fault condition, the equipment or relevant part shall meet the requirements of 4.10.4.

Single fault condition assessment shall include the following.

4.10.2.2 Protective impedance

The following requirements apply.

- If protective impedance is formed by a combination of components, each component shall in turn be short-circuited or disconnected.
- If protective impedance is formed by a combination of basic insulation and a voltage- or current-limiting device, both the basic insulation and the voltage- or current-limiting device shall be subjected to single faults, applied one at a time. Basic insulation shall be short-circuited. The voltage- or current-limiting device shall be short-circuited or disconnected, whichever is less favourable.

Parts of a protective impedance which are high-integrity components need not be short-circuited or disconnected.

4.10.2.3 Transformers

Transformer non-primary windings and sections of tapped windings, which are loaded under normal ~~conditions~~ use shall be tested in turn, one at a time, to simulate short circuits in the load. All other windings are loaded or not loaded, whichever load condition is less favourable.

The primary and non-primary windings of the transformer shall have a short circuit applied between them unless separated by reinforced or double insulation. The reinforced or double insulation shall be tested where thermal damage to the insulation ~~may~~ can create a risk of electric shock.

Short circuits shall also be made on the load side of any current-limiting impedance or over-current protective device which is connected directly to the winding.

4.10.2.4 Outputs

Outputs shall be short-circuited one at a time.

4.10.2.5 Insulation between circuits and parts

Functional insulation between circuits and parts shall be short-circuited where this could cause overheating of any material creating a risk of fire, unless that material is of flammability class V-1 or better of IEC 60695-11-10.

Basic insulation in primary circuits ~~with less than the specified clearance distance~~ shall be bridged to check against the spread of fire.

Supplementary, reinforced and double insulation need not be short-circuited. The exception to this is where thermal damage to the insulation ~~may~~ can create a risk of electric shock.

4.10.2.6 Primary circuits and hazardous voltage non-primary circuits

Single fault conditions shall be applied by open-circuiting or short-circuiting components in primary circuits and hazardous voltage non-primary circuits, within the equipment, where these ~~may~~ can create a risk of electric shock or fire.

4.10.2.7 Overloads

Single fault conditions shall be applied where a circuit or component overload ~~may~~ can create a fire or electric shock hazard. This includes connection of the most unfavourable load impedances to terminals and connectors which deliver power or signal outputs from the equipment.

It is permitted to use fusible links, overcurrent protection devices and the like to provide adequate protection.

Where there are multiple ~~outlets~~ ports with the same internal circuitry, the single fault test can be limited to one ~~outlet~~ port only.

4.10.2.8 Intermittently rated resistors

Continuous dissipation in resistors designed for intermittent dissipation shall be considered under the single fault condition assessment.

4.10.2.9 DC inputs

DC inputs shall be assessed for effects of reverse polarity under worst case conditions.

It is permitted to use fusible links, overcurrent protection devices and the like to provide adequate protection.

Where there are multiple ~~inlets~~ ports with the same internal circuitry, the test can be limited to one ~~inlet~~ port only.

4.10.3 Duration of tests

The equipment shall be operated until further change as a result of the applied fault is unlikely. Each test is normally limited to one hour since a secondary fault arising from a single fault condition will usually manifest itself within that time. If there is an indication that a risk of electric shock, spread of fire or injury to persons ~~may~~ can eventually occur, for example if the temperature has not stabilized, the test shall be continued ~~until one of these hazards does occur~~ or for a maximum period of four hours unless a hazard occurs before then.

4.10.4 Compliance

4.10.4.1 ~~Compliance~~ Conformity with requirements for electric shock protection

4.10.4.1.1 General

A dielectric voltage withstand test according to 9.6.4.3 ~~may~~ shall be ~~necessary~~ performed before and after a single fault test to demonstrate that the equipment does not present an electric shock hazard following the application of a single fault condition.

PEB, PELV and SELV circuits shall remain safe to touch after the application of a single fault condition.

Following a single fault condition, accessible parts shall not be hazardous live, as defined in 4.10.4.1.2.

4.10.4.1.2 Values in single fault condition

Values in single fault conditions are given below. ~~Values exceeding the levels/limits of items a) to c) due to a single fault condition are deemed to be hazardous live. The limits of items b) and c) apply only if the voltage exceeds the values of item a).~~ Voltages above the levels of a) are deemed to be hazardous live if any of the levels of b) or c) are exceeded at the same time.

- a) Voltage levels are ~~55 V r.m.s. or 140 V d.c.~~ 50 V AC RMS or 120 V DC **10**

For ~~temporary~~ voltages of short duration, the duration versus voltage levels are those of Figure 2 of IEC 61010-1:2010/AMD1:2016, measured across a 50 kΩ resistor.

For equipment rated for use in wet locations, the voltage levels are 33 V AC RMS or 70 V DC

- b) Current levels are as shown in Table 5.

Table 5 – Current levels in single fault condition

Installation location	Figure 3 ~~or~~ Figure 4 of IEC 60990:49992016 Measurement circuit to be used	Sinusoidal waveforms mA AC RMS	Non-sinusoidal or mixed frequency waveforms mA AC peak	mA DC
Dry	Figure 4	3,5	5	15
Wet	Figure 3 with $R_S = 375 \Omega$ (instead of 1 500 Ω)	3,5	5	15
Dry	Figure 3 with $R_B = 75 \Omega$ Relates to possible burns in the frequency range 30 kHz to 500 kHz	500	-----	-----

c) The capacitance level is that defined in Figure 3 in IEC 61010-1:2010.

4.10.4.2 ~~Compliance~~ **Conformity** with requirements for temperature protection

Refer to 6.3.1.

4.10.4.3 ~~Compliance~~ **Conformity** with requirements for protection against the spread of fire

Refer to 6.10.3.

4.10.4.4 ~~Compliance~~ **Conformity** with requirements for hazardous gases and chemicals

Refer to 6.3.2.

4.10.4.5 ~~Compliance~~ **Conformity** with requirements for mechanical protection

~~Compliance~~ **Conformity** with requirements for mechanical protection is checked by inspection to ensure that no parts are expelled from the equipment due to parts exploding or imploding and that no mechanical hazard is caused by the application of a single fault condition.

The means of protection against expelled parts should not be removable without the aid of a tool. If the protection is removable without the use of a tool, symbol 14 from Table 12 shall be used, and an appropriate warning provided in the documentation.

5 Mechanical aspects

5.1 Protection against mechanical hazards

5.1.1 Stability

Under conditions of normal use, equipment shall not become physically unstable to the degree that it could become a hazard to the user.

Conformity of stability is checked by inspection.

5.1.2 Moving parts

Moving parts shall not be able to crush, cut or pierce parts of the body of the user likely to come into contact with them, nor severely pinch the user's skin under normal ~~conditions~~ **use** and maintenance **use**. This requirement does not apply to easily touched moving parts which are obviously intended to operate on parts of materials external to the equipment, for example

tripping mechanism. Such equipment should be designed to minimize inadvertent touching of such moving parts (for example, by fitting of guards, handles, etc.).

~~Compliance~~ Conformity of moving parts is checked by inspection.

5.1.3 Edges and corners

All easily touched edges, projections, corners, openings, guards, handles and the like of the equipment case should be smooth and rounded so as not to cause injury during normal ~~conditions~~ use.

~~Compliance with 6.1.3 is checked by inspection.~~

Conformity of edges and corners is checked by inspection and, if necessary, by application of an object that represents a finger in size, shape and hardness, to check for abrasions and cuts.

NOTE An acceptable procedure that can be used is outlined in UL 1439.

5.2 Mechanical requirements

The equipment ~~should~~ shall, when mounted in accordance with the manufacturer's instructions, comply with the mechanical tests in 9.6.2.1 to 9.6.2.4.

Where higher severity levels are required, they shall be agreed between the manufacturer and the user.

5.3 Mechanical security of terminations

Refer to Annex E.

6 Flammability and resistance to fire

6.1 General

This Clause 6 provides methods and procedures to reduce the risk of fire associated with the equipment to a safe level, by one of the following means:

- eliminating or reducing the sources of ignition within the equipment.
- reducing the amount of combustible (or flammable) materials within the equipment;
- containment of a fire within the equipment, should it occur.

6.2 ~~Rationale~~ Requirements for protection against the spread of fire

It is possible that equipment or parts of equipment ~~may~~ cause excessive temperatures, under normal ~~condition~~ use or single fault condition, which could lead to a risk of fire within the equipment or to its surroundings.

In order for a risk of fire within the equipment to exist, all three of the following basic elements shall exist.

- 1) The equipment circuits ~~shall~~ have sufficient power or energy to be an ignition source.
- 2) There ~~shall be~~ is oxygen present (air is about 21 % oxygen).
- 3) There ~~shall be~~ are combustible materials present to support the combustion process.

The use of the methods and procedures within this Clause 6 offers the following benefits:

- ~~Compliance~~ conformity with fire-protection requirements without tests;

- reduction of single fault condition testing;
- specification of construction methods which allow verification of fire protection by inspection;
- reduction of interpretation differences and testing variables between inspection authorities.

This Clause 6 also details requirements for protection against the spread of fire, maximum temperature limits and limited energy circuits (see 6.11).

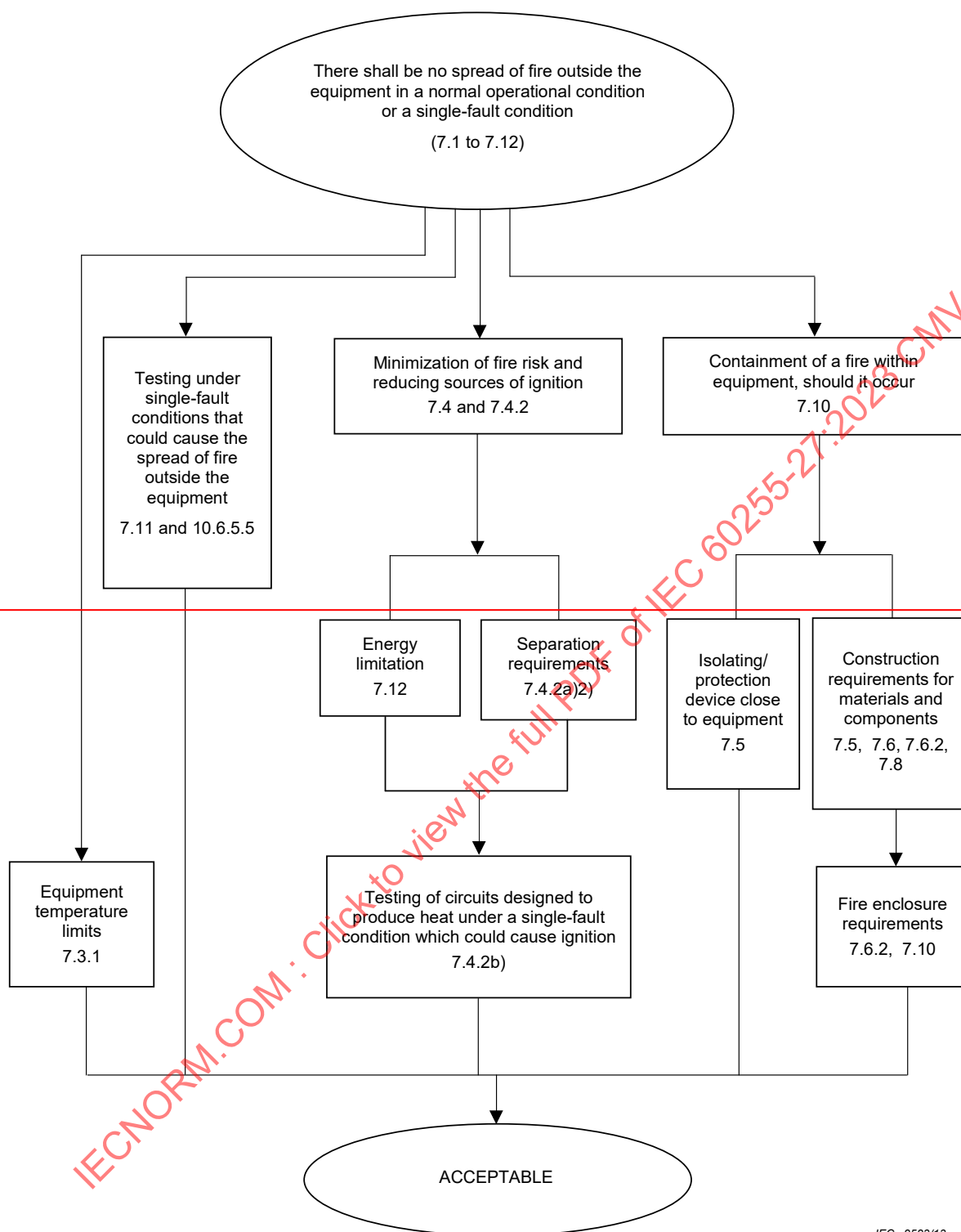
~~The flow chart in Figure 1 shows requirements for protection against the spread of fire.~~

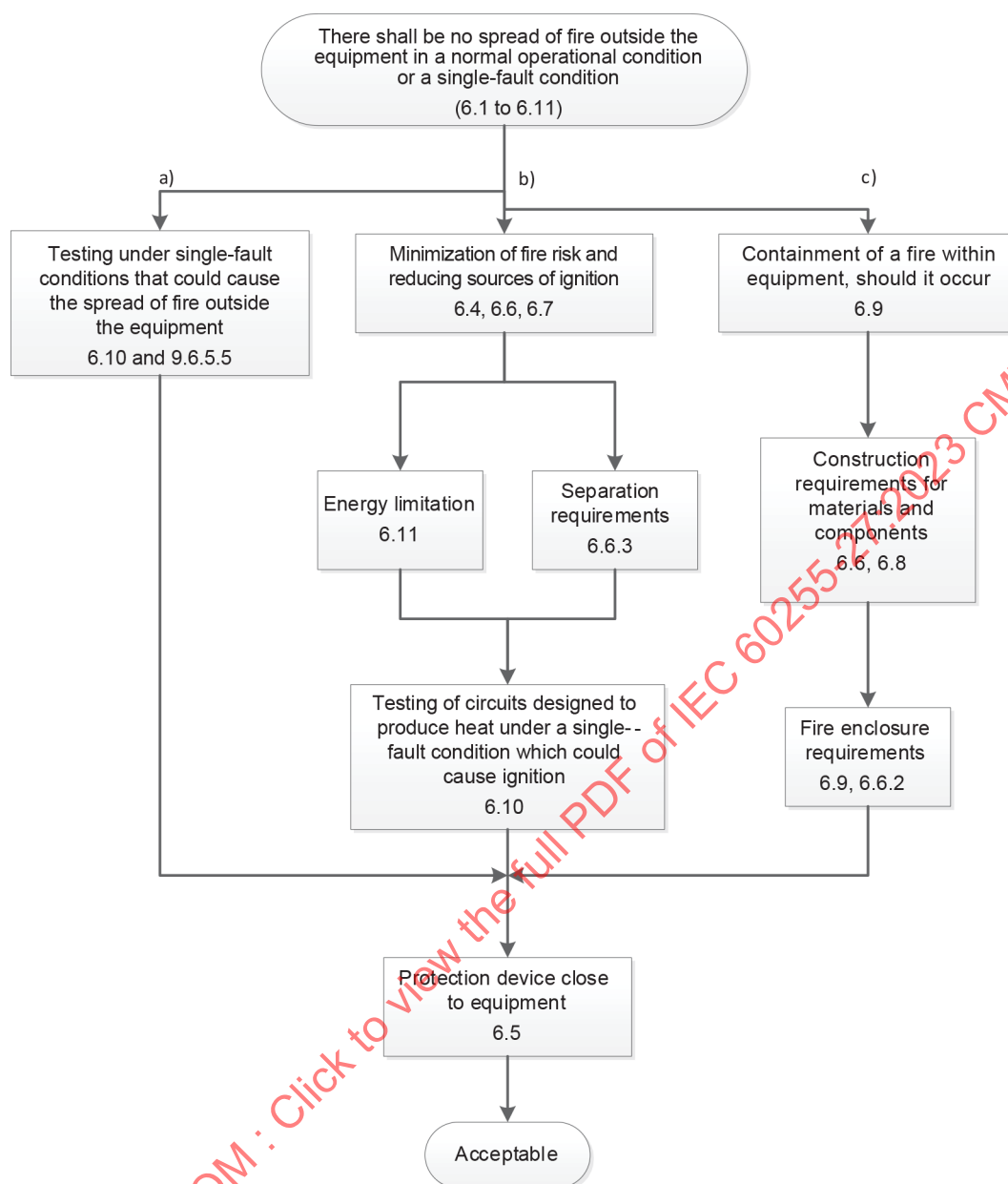
There shall be no spread of fire outside the equipment in normal use or in single fault condition. Figure 1 is a flow chart showing methods of conformity verification.

Conformity is checked against the requirements for a protection device (see 6.5) and by at least one of the following methods.

- a) Testing in the single fault conditions (see 6.10 and 9.6.5.5) that could cause the spread of fire outside the equipment. The conformity criteria of 6.10.3 shall be met.
- b) Verifying elimination or reduction of the sources of ignition within the equipment as specified in 6.4.1 and 6.4.2 or 6.4 and 6.11.
- c) Verifying, as specified in 6.9, that if a fire occurs it will be contained within the equipment.

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Figure 1 – Flow chart showing requirements for protection against the spread of fire

6.3 General hazards from overheating and fire

6.3.1 **Equipment** Surface temperature limits for protection against burns

Heating shall not cause a hazard under normal-conditions use or single fault conditions, nor shall it cause spread of fire outside the equipment. Table 6 specifies the maximum acceptable temperatures under normal-conditions use at maximum ambient temperature. The temperatures in Table 6 can be exceeded under the following conditions.

- For areas unlikely to be touched, with no dimension exceeding 50 mm, 100 °C is allowable.
- Temperatures exceeding the limits, which are for an ambient temperature of 40 °C, are permitted provided that unintentional contact is unlikely and the part has a warning indicating that it is hot, for example, symbol 13 (or 14) of Table 12.

Refer to 4.10 for the maximum acceptable temperatures under a single fault condition.

If easily touched heated surfaces are necessary for functional reasons, they are permitted to exceed the values in Table 6, but shall be recognizable as such by appearance or function or shall be marked. Symbol 13 of Table 12 should be used to indicate that a surface or part is hot.

~~Consideration should be given to the fact that, on a long-term basis, the electrical and mechanical properties of some insulating materials may be adversely affected, for example, by softeners evaporating at temperatures below the normal softening temperature of the material.~~

~~The relative thermal index (RTI), where specified for the material, provides the maximum continuous operating temperature at which its electrical and mechanical properties may reduce by up to 50 % over a period of 7 years.~~

Table 6 – Maximum temperature under normal ~~conditions~~ use and at an ambient temperature of 40 °C

Accessible parts under normal ~~conditions~~ use	Maximum temperature °C	
	Metal	Non-metallic
Handles, knobs, grips, etc. held or touched for short periods only	60	85
Handles, knobs, grips, etc. continuously held under normal ~~conditions~~ use	55	70
External surfaces of equipment which ~~may~~ can be touched	70	80
Parts inside the equipment which ~~may~~ can be touched	70	80

~~Compliance~~ Conformity with 6.3.1 is checked by measurement and by inspection of guards and covers, to check that they protect against accidentally touching surfaces that are at temperatures above the values in Table 6. All guards and covers shall be in place when conducting the test. If the guards or covers can be removed without the aid of a tool, symbol 13 or symbol 14 of Table 12 shall be used.

6.3.2 Hazardous gases and chemicals

The equipment shall not liberate ~~dangerous~~ hazardous amounts of poisonous or injurious gases under normal operation.

The manufacturer's documentation shall state which potentially poisonous or injurious gases ~~may~~ can be liberated, and the quantities.

Conformity is checked by inspection of the manufacturer's documentation. The wide variety of gases makes it impossible to specify conformity tests based on limit values, so reference should be made to tables of occupational threshold limit values.

6.4 Minimization of fire risk

6.4.1 General

The minimization of fire risk, both within the equipment and to cabling and wiring, shall be a major consideration. Protection consistent with reliability and operational requirements shall be provided.

In the event of a single fault condition, any damage shall be contained within the equipment (see 6.10).

Components and materials shall be chosen and used so that there is negligible risk of a fire being caused due to component failure or possible short circuit.

Safety critical components of primary circuits and circuits exceeding ELV voltage limits should comply with relevant component standards; refer to Annex D for information. The equipment and its circuit diagrams shall be examined to determine if single fault condition tests are necessary to demonstrate that there is a negligible risk of fire.

6.4.2 Eliminating or reducing the sources of ignition within the equipment

6.4.2.1 General

The risk of ignition and occurrence of fire is ~~considered to be~~ reduced to a tolerable level if one of the following requirements is met for each source of ignition hazard.

~~a) Either 1) or 2)~~

- ~~1) The voltage, current and power available to the circuit or part of equipment is limited as specified in 7.12.~~

~~Conformity is checked by measurement of limited-energy values as specified in 7.12.~~

- ~~2) Insulation between parts at different potentials meets the requirements for basic insulation, or it can be demonstrated that bridging the insulation will not cause ignition.~~

~~Conformity is checked by inspection and in case of doubt by test, applying the criteria of 7.11.~~

- ~~b) In circuits designed to produce heat, no ignition occurs when tested in any single fault condition (see 5.2) which could cause ignition.~~

~~All circuits of the equipment which cannot be classified as limited-energy circuits (see 7.12) are considered to be an ignition source of fire, in which case either method i) or ii) below shall be used.~~

- ~~i) Testing in the single-fault conditions (see 5.2) which could cause the spread of fire outside the equipment.~~

- ~~ii) Verifying as in 7.11 that if a fire occurs it will be contained within the equipment.~~

~~Conformity is checked by the relevant tests of 5.2, applying the criteria of 7.11.~~

6.4.2.2 Limited power **11**

The voltage, current and power available to the circuit or part of equipment are limited as specified in 6.11. Conformity is checked by measurement of limited-energy values as specified in 6.11.

6.4.2.3 Basic insulation

Insulation between parts at different potentials shall meet the requirements for basic insulation, or it shall be demonstrated that short-circuiting the insulation will not cause ignition. Conformity is checked by inspection or by the relevant tests of 9.6.5, applying the criteria of 6.10.

6.4.2.4 Ignition sources

Circuits of the equipment which cannot be classified as limited-energy circuits (see 6.11) are considered ignition sources, in which case conformity is checked by the relevant tests of 9.6.5, applying the criteria of 6.10.

6.5 Cabling and fusing

The manufacturer shall recommend the following to minimize the risk of fire and thermal overload of the AC or DC supply and protective conductors or other equipment fed by the product, taking into account worst-case single fault conditions.

- Connection cables: minimum cross-section and voltage rating.

- Protection devices: fuse or circuit-breaker rating; it should be close to the equipment and should include the protection device characteristic and voltage rating.

NOTE Failures or faults can be due to short circuits within the equipment or to accessible conductive parts, earth faults, short circuit in the output circuits, or control circuit failure. Cabling and fusing is of importance when:

- under use as intended, a fault in the equipment can cause the rated output current of the equipment to be exceeded, resulting in thermal overload of the protective conductor or other equipment fed by the equipment; and
- the equipment fault does not automatically cause a disconnection to its AC or DC supply.

6.6 Flammability of materials and components

6.6.1 General

See Table 14 for the test overview, including flammability.

Conformity is checked by inspection of data on materials, or by performing the flammability tests specified in IEC 60695-11-10 on three samples of the relevant parts (see Table 14 and 9.6.5 of this document). The samples may be any of the following:

- a) complete parts and assemblies of materials as used in product;
- b) sections of a part, including the area with the least wall thickness and any ventilation openings;
- c) ~~specimens~~ samples in accordance with IEC 60695-11-10.

Where safety is involved, components shall meet one of the following:

- the flammability requirements of a relevant IEC component standard which includes such requirements;
- where no relevant IEC standard exists, the flammability requirements of this document;
- applicable flammability requirements of a non-IEC standard where these are at least as high as those of the relevant IEC standard, provided that the component has been approved to the non-IEC standard by a recognized testing authority.

6.6.2 Materials for components and other parts inside fire enclosures

Materials for use within fire enclosures shall comply with any of the following.

- a) Electrical components which do not present a fire hazard under abnormal operating conditions when tested according to 4.10.
- b) Materials and components within an equipment case of volume 0,06 m³ or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas.
- c) One or more layers of thin insulating material, such as adhesive tape, used directly on any surface within the fire enclosure, including the surface of current-carrying parts, provided that the combination of the thin insulating material and the surface of application comply with the requirements of flammability class V-2, or better, of IEC 60695-11-10. Where the thin insulating material is on the inner surface of the fire enclosure itself, the requirements for fire enclosure construction in 6.9 apply.
- d) Electronic components, such as integrated circuit packages, opto-coupler packages, capacitors and other small parts mounted on material of flammability class V-1, or better, of IEC 60695-11-10.
- e) Wiring, cables and connectors insulated with PVC, TFE, PTFE, FEP or neoprene or polyimide or insulated wire ~~with a flammability class equivalent V-1, or better, of IEC 60695-11-10~~ that retards flame propagation, as determined by conformity with the recommended performance requirements in the applicable parts of IEC 60332.

NOTE Wire with a flammability RATING of UL 2556 VW-1 or equivalent is considered to meet this requirement.

- f) Individual clamps (not including helical wraps or other continuous forms), lacing tape, twine and cable ties used with wiring harnesses.

Compliance **Conformity** with 6.6.1 and 6.6.2 is checked by inspection of the equipment and material data sheets.

6.6.3 Materials for fire enclosures

Materials for components which fill an opening in a fire enclosure, and which are intended to be mounted in that opening shall:

- be of flammability class V-1, or better, of IEC 60695-11-10; or
- pass the flammability test of IEC 60695-11-10; or
- comply with the flammability requirements of the relevant IEC component standard.

NOTE Examples of these components are fuse-holders, switches, connectors and appliance inlets.

Plastic materials of a fire enclosure shall be located more than 13 mm through air from arcing parts such as unenclosed switch contacts.

Plastic materials of a fire enclosure located less than 13 mm through air from non-arcing parts which, under any condition of normal or abnormal operation, could attain a temperature sufficient to ignite the material, shall be capable of passing the test of IEC 60695-2-20. The average time to ignition of the samples shall be not less than 15 s. If a sample melts through without igniting, the time at which this occurs is not considered to be the time to ignition.

Compliance **Conformity** with 6.6.3 is checked by inspection of the equipment and material data sheets and, if necessary, the appropriate flammability test.

6.6.4 Materials for components and other parts outside fire enclosures

Except as otherwise noted below, materials for components and other parts (including mechanical enclosures, electrical enclosures and decorative parts), located outside fire enclosures, shall have a minimum flammability class HB75 according to IEC 60695-11-10 if the thinnest significant thickness of this material is < 3 mm, or flammability class HB40 according to IEC 60695-11-10 if the thinnest significant thickness of this material is ≥ 3 mm, or flammability class HBF. Where a mechanical or an electrical enclosure also serves as a fire enclosure, the requirements for fire enclosures apply (see 6.6.3 and 6.9).

The above flammability requirements do not apply to any of the following:

- a) electrical components which do not present a fire hazard under abnormal operating conditions when tested according to 4.10;
- ~~materials and components within an enclosure of 0,06 m³ or less, consisting totally of metal and having no ventilation openings or within a sealed unit containing an inert gas;~~
- b) components meeting the flammability requirements of a relevant IEC component standard which includes such requirements;
- c) electronic components, such as integrated circuit packages, opto-coupler packages, capacitors and other small parts that are:
 - 1) mounted on material of flammability class V-1, or better, of IEC 60695-11-10;
 - 2) supplied from a power source of no more than 15 VA, or that complies with limited-energy circuit requirements (see 6.11), under normal operating conditions or after a single fault in the equipment and mounted on material of flammability class HB75 according to IEC 60695-11-10 if the thinnest significant thickness of this material is < 3 mm, or flammability class HB40 according to IEC 60695-11-10 if the thinnest significant thickness of this material is ≥ 3 mm.

Connectors shall comply with one of the following:

- be made of material of flammability class V-1, or better, of IEC 60695-11-10;
- pass the tests of IEC 60695-11-10;
- comply with the flammability requirements of the relevant IEC component standard;
- be located in a secondary circuit supplied by a power source that is limited to a maximum of 15 VA or that complies with limited-energy circuit requirements (see 6.11) under normal operating conditions and after a single fault in the equipment (see 4.10).

Terminal blocks shall comply with the following:

- be made of material of flammability class V-1, or better, of IEC 60695-11-10;
- comply with the temperature limits for the relevant material with maximum load current applied.

6.7 Fire ignition sources

All circuits of equipment which can be classified as including primary circuits or circuits exceeding ELV voltage limits shall be considered to be an ignition source of fire. All electrical components of such circuits are considered likely to be an ignition source of fire.

6.8 Conditions for a fire enclosure

~~7.8.1 General~~

~~A fire enclosure is required when temperatures of parts under fault conditions could be sufficient for ignition.~~

6.8.1 Parts requiring a fire enclosure

The following are considered to have a risk of ignition and therefore require a fire enclosure:

- components in primary circuits or exceeding ELV voltage limits. Except where equipment ~~has had~~ meets the requirements of all the applicable single fault tests of 4.10 ~~applied~~;
- components in non-primary circuits supplied by power sources which exceed the limits specified in 6.11;
- components in non-primary circuits supplied by a source complying with limited-energy circuits as specified in 6.11, but not mounted on material of flammability class V-1, or better, of IEC 60695-11-10;
- components within a power supply unit or assembly having an output complying with a limited-energy circuit, as specified in 6.11, including overcurrent protective devices, limiting impedances, regulating networks and wiring (see 6.8.2 for exceptions), up to the point where the source output criteria for a limited-energy circuit are met;
- components having unenclosed arcing parts, such as open switch and relay contacts in a circuit at hazardous voltage or at a hazardous energy level;
- insulated wiring, except as permitted in 6.8.2.

6.8.2 Parts not requiring a fire enclosure

The following do not require a fire enclosure:

- motors;
- transformers;
- electromechanical components complying with 6.6;
- components, including connectors, meeting the requirements of 6.6.4, which fill an opening in a fire enclosure;
- wiring and cables insulated with PVC, PTFE, TFE, FEP, neoprene or polyimide;
- plugs and connectors forming part of a power supply cord or interconnecting cable;

- g) connectors in non-primary circuits supplied by power sources which are limited to a maximum of 15 VA under normal operating conditions and after a single fault in the equipment;
- h) connectors in non-primary circuits supplied by limited-energy circuits complying with 6.11;
- i) other components in non-primary circuits:
 - 1) supplied by a limited-energy circuit complying with 6.11 and mounted on materials of flammability class V-1 or better, of IEC 60695-11-10;
 - 2) supplied by internal or external power sources which are limited to a maximum of 15 VA under normal operating conditions and after a single fault in the equipment and mounted on material having a minimum flammability class HB75 according to IEC 60695-11-10, if the thinnest significant thickness of this material is < 3 mm or flammability class HB40 according to IEC 60695-11-10 if the thinnest significant thickness of this material is ≥ 3 mm;
- j) equipment which has had all the applicable single fault tests of 4.10 applied to both the primary and non-primary circuits;
- k) small parts, such as paper labels, up to 1 500 mm².

If the components become excessively hot under a single fault condition and are mounted within 13 mm of non-metallic materials of V-2 rating or worse, then a hot wire ignition (HWI) test to IEC 60695-2-12 can be carried out on the non-metallic material, of minimum thickness, to determine if there is a risk of fire.

~~Compliance~~ **Conformity** with 6.8.1 and 6.8.2 is checked by inspection and by evaluation of the data provided by the manufacturer. In the case where no data is provided, ~~compliance~~ **conformity** is determined by **flammability** tests.

6.9 ~~Requirements for primary circuits and circuits exceeding ELV limits~~ **Fire enclosures and flame barriers**

6.9.1 General

The risk of fire in primary circuits and circuits exceeding ELV limits shall be considered to be reduced to a tolerable level if such circuits of the equipment, and the equipment case, comply with the constructional requirements of 6.9 ~~or the transformers etc., have overcurrent or over-temperature protection which complies with the relevant IEC standard.~~

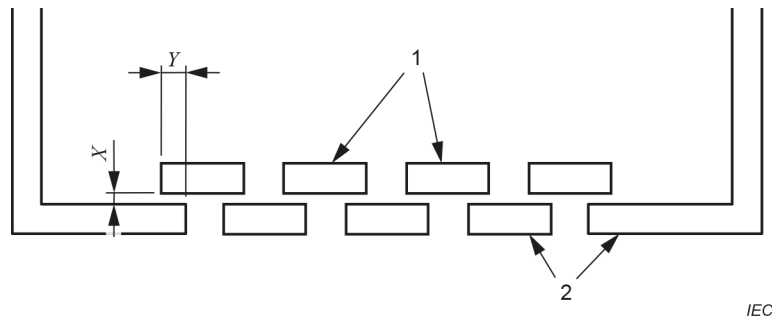
6.9.2 Fire enclosures and flame barrier requirements

The fire enclosure shall meet the following requirements.

- The bottom shall have no openings or, to the extent in Figure 3, shall be constructed with baffles as specified in Figure 2 or be made of metal, perforated as specified in Table 7 or be a metal screen with a mesh not exceeding 2 mm × 2 mm centre to centre and a wire diameter of at least 0,45 mm.
- ~~The sides shall have no openings within the area that is included within the inclined line C in Figure 3.~~
- The equipment case, and any baffle or flame barrier, shall be made of metal (except magnesium) or of non-metallic materials having a flammability class of V-1, or better, of IEC 60695-11-10.
- The equipment case, and any baffle or flame barrier, shall have adequate ~~rigidity~~ **mechanical strength** to protect against electric shock in accordance with Clause 4.

A flame barrier and the bottom of a fire enclosure are considered to comply without test, if in the smallest thickness used, the material is of flammability class V-1 of IEC 60695-11-10 or better.

~~Compliance~~ **Conformity** with 6.9 is checked by inspection. In case of doubt the flammability class of V-1, or better, is checked on three samples according to IEC 60695-11-10.



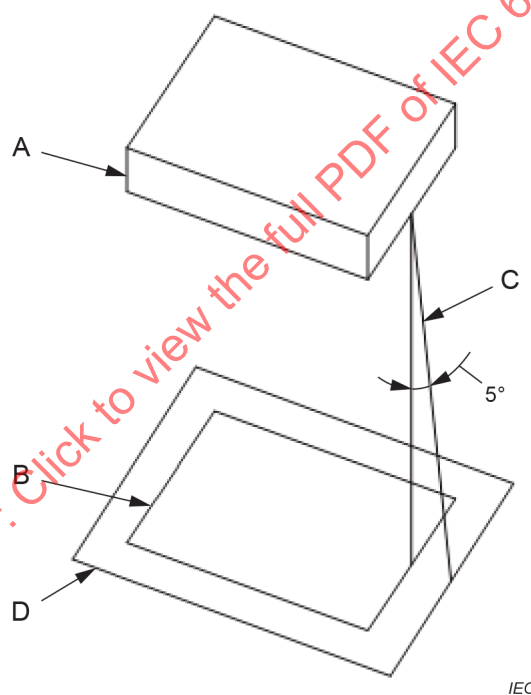
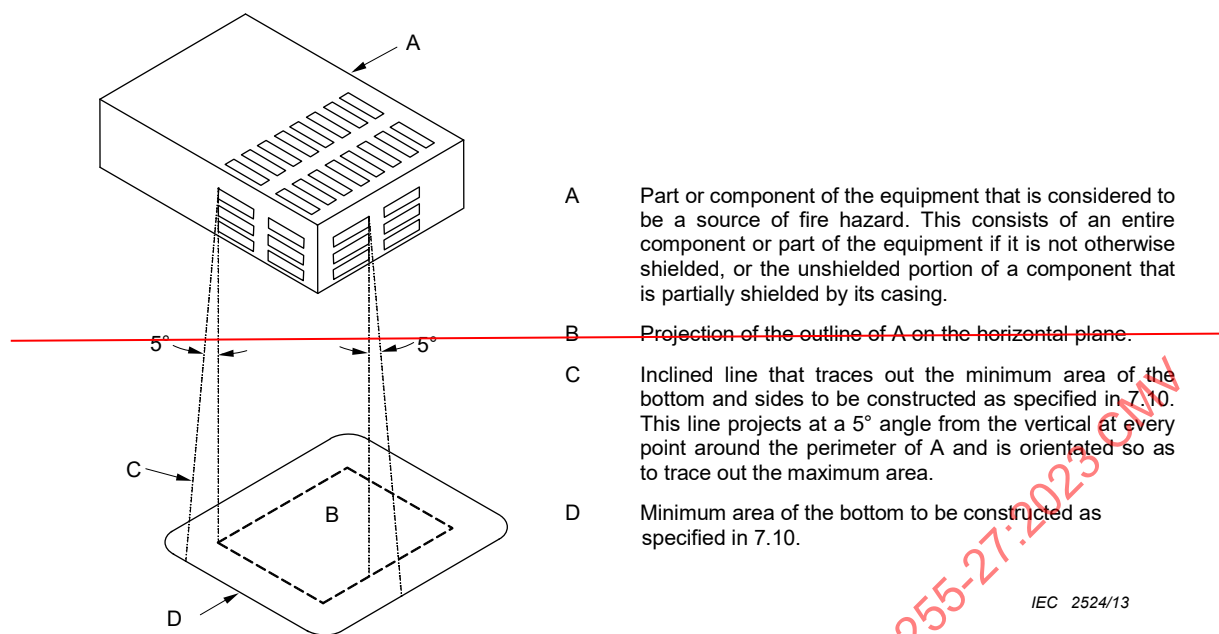
$Y = 2X$ but never less than 25 mm

Key

- 1 Baffle plates (may be below the bottom of the enclosure)
- 2 Bottom of enclosure

Figure 2 – Baffle

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Key

- A Part or component of the equipment that is considered to be a source of fire hazard. This consists of an entire component or part of the equipment if it is not otherwise shielded, or the unshielded portion of a component that is partially shielded by its casing.
- B Projection of the outline of A on the horizontal plane.
- C Inclined line that traces out the minimum area of the bottom and sides to be constructed as specified in 6.9. This line projects at a 5° angle from the vertical at every point around the perimeter of A and is orientated so as to trace out the maximum area.
- D Minimum area of the bottom to be constructed as specified in 6.9.

Figure 3 – Location and extent of a flame barrier

Table 7 – Acceptable perforation in the bottom of an equipment case

Minimum thickness	Maximum dimension of holes ^a	Minimum spacing of holes centre to centre
mm	mm	mm
0,76	1,15	1,70
0,76	1,19	2,36
0,81	1,91	3,18 ~~(72 holes/645 mm²)~~
0,89	1,90	3,18
0,91	1,60	2,77
0,91	1,98	3,18
1,00	1,60	2,77
1,00	2,00	3,00

NOTE ^a The diagonal is the maximum dimension for a square hole.

6.10 Assessment of the fire risk due to a single fault condition

6.10.1 Guidelines for maximum acceptable temperatures when subjecting a circuit or component to a single fault condition

Where it is not practical to protect components against overheating, under a single fault condition, the components shall be mounted on materials of flammability class V-1 or better, of IEC 60695-11-10. Additionally, such components shall be separated from material of a class lower than flammability class V-1 by at least 13 mm of air or by a solid barrier of material of flammability class V-1, or better.

The temperatures specified shall be at the hottest point on the surface of a component or material or within it.

Where it is not possible to meet the above criteria for components and/or circuits subject to overheating under fault conditions, these should be effectively shielded or separated to prevent overheating of their surrounding materials and components (see 6.9). Alternatively, the equipment, mounted under ~~normal conditions may~~ normal use should be subjected to the ~~compliance~~ conformity test in 6.10.3.

6.10.2 Temperature of windings under normal ~~condition~~ use or a single fault condition

If a hazard could be caused by excessive temperature, the temperature of the insulating material of windings shall not exceed the values of Table 8 in normal ~~condition~~ use or single fault condition. The values in Table 8 are not applicable for short term overloads. If the temperature of a winding is determined using thermocouples, the values in the table are reduced by 10 °C, except in the case of ~~a motor, or~~ a winding with embedded thermocouples.

~~Compliance~~ Conformity with 6.10.2 is checked by measurement in the normal ~~condition~~ use and in the applicable single fault condition.

Table 8 – Insulation material of windings

Class of insulation (as defined in IEC 60085)	Normal ~~conditions~~ use °C	Single fault condition °C
Class A	105	150
Class B	130	175
Class E	120	165
Class F	155	190
Class H	180	210

6.10.3 ~~Compliance~~ Conformity of equipment with requirements for protection against the spread of fire

Refer to 9.6.5.5 for single fault testing.

~~Compliance~~ Conformity of equipment to 6.10.3 with requirements for protection against the spread of fire is checked, as a safety type test, by placing the equipment on wrapping tissue (wrapping paper of between 12 g/m² and 30 g/m²), covering a softwood surface and covering the equipment with a single layer of cheesecloth (bleached cotton of approximately 40 g/m²). No molten metal, burning insulation, flaming particles, etc., shall fall on the surface on which the equipment stands, and there shall be no charring, glowing, or flaming of the tissue paper or cheesecloth. Melting of insulation material which is not of importance to the requirements of this document shall be ignored.

6.11 Limited-energy circuit

A limited-energy circuit is a circuit that meets all the following criteria.

- a) The potential appearing in the circuit is not more than ~~33 V r.m.s. or 70 V d.c.~~ 30 V AC RMS or 60 V DC. **12**
- b) The current that can appear in the circuit is limited by one of the following means:
 - 1) the maximum available current is limited inherently or by impedance so that it cannot exceed the relevant value of Table 9;
 - 2) current is limited by an overcurrent protective device according to Table 10;
 - 3) a regulating network limits the maximum available current so that it cannot exceed the relevant value of Table 9 under normal ~~conditions~~ use or as a result of one fault in the regulating network.
- c) It is separated by at least basic insulation from other circuits that would result in energy values exceeding criteria a) and b) above.

If an overcurrent protective device is used, it shall be a fuse or a non-adjustable non-self-resetting electromechanical device.

Conformity to 6.11 is checked by inspection and by measuring the potentials appearing in the circuit, the maximum available current, under the following conditions.

- The potentials appearing in the circuit are measured in the load condition that maximizes the voltage.
- Output current is measured after 60 s of operation, with the resistive load (including short circuit) which produces the highest value of current.

Table 9 – Limits of maximum available current

Open-circuit output voltage, U			Maximum available current A
V			
AC RMS	DC	Peak ^a	
≤ 20	≤ 20	$\leq 28,3$	8
$20 < U \leq 30$	$20 < U \leq 30$	$28,3 < U \leq 42,4$	8
–	$30 < U \leq 60$	–	$150/U$

^a The peak value applies to non-sinusoidal AC and to DC with ripple exceeding 10 %.

Table 10 – Overcurrent protective device

Potential appearing in the circuit, U			Current that the protection device breaks after not more than 120 s ^b
V			A
AC RMS	DC	Peak ^a	
≤ 20	≤ 20	$\leq 28,3$	10
$20 < U \leq 30$	$20 < U \leq 60$	$28,3 < U \leq 42,4$	$200/U$

^a The peak value applies to non-sinusoidal AC and to DC with ripple exceeding 10 %.

^b The evaluation should be based on the specified time-current breaking characteristics of the protection device (which is different from the rated breaking current). (For example, in IEC 60127-1, a 4 A, T-type fuse is specified to break at 8,4 A or less at 120 s.) The breaking current of fuses is dependent on temperature and this should be taken into account if the ambient temperature of a fuse is significantly higher than the room ambient temperature.

7 General and fundamental design requirements for safety

7.1 Climatic conditions for safety

Climatic conditions of equipment denote the conditions in the immediate environment.

The equipment safety shall not be impaired by the environmental ranges declared by the manufacturer. These conditions include:

- temperature, operation and storage;
- humidity, non-condensing;
- atmospheric pressure.

7.2 Electrical connections

The design of electrical terminations and connection points shall be such that the expected reliability will be maintained throughout the life of the equipment. Allowance shall be made for the conditions normally encountered in service, for example, corrosion due to humidity, shocks, heat and creep.

Compliance Conformity of protective bonding with 7.2 shall be verified by test.

Wires and cables shall be in accordance with the relevant IEC standards.

Conductors and their cross-sections shall comply with the electrical, mechanical and climatic requirements of this document. Furthermore, the structure of the conductors and their cross-

sections shall be matched to the connection method used. For example, connection method without screws or soldering shall be in accordance with IEC 60352-1 or IEC 60352-2.

Current-carrying parts ~~should~~ shall have the necessary mechanical strength and current-carrying capacity for their intended use. Current transformer primary windings should be restrained mechanically to ensure circuit continuity is maintained during thermal withstand conditions. **13**

For electrical connections, no contact pressure ~~should~~ shall be transmitted through insulating material other than ceramic or other material with characteristics no less suitable, unless there is sufficient resilience in the metallic parts to compensate for any possible shrinkage or yielding of the insulation material.

7.3 Components

7.3.1 General

Refer to Annex D for safety-related guidance on the design and application of components for use in equipment within the scope of this document.

7.3.2 High-integrity part or component **14**

~~High-integrity parts or components shall be used in positions (see 5.1.4 and 5.2.2.2) where if short-circuiting or disconnection occurred, an infringement of the requirements in a single fault condition would be caused. High-integrity parts and components shall be constructed, dimensioned and tested to IEC publications (where applicable) so that safety and reliability for the expected application is assured. They may be regarded as fault-free in relation to this standard.~~

~~Examples of such requirements and tests are:~~

- ~~• dielectric voltage tests appropriate to double or reinforced insulation;~~
- ~~• dimensioning of at least twice the dissipation (resistor);~~
- ~~• climatic tests and endurance tests to ensure reliability throughout the life of the equipment;~~
- ~~• withstand test for resistors, i.e. either an impulse voltage withstand test to IEC 61180-1, source impedance 2 Ω , or a dielectric voltage test. The withstand test voltage shall be determined from Table C.9 or Table C.10.~~

Where short-circuiting or disconnection of a component in a single-fault condition could result in a hazard, high-integrity components shall be used.

High-integrity parts and components are regarded as fault-free in relation to the requirements of this document and are not subject to testing in single-fault conditions.

NOTE In addition to the requirements of this document, high-integrity parts and components are constructed, dimensioned and tested according to IEC publications (where applicable) so that their safety and reliability for the expected application is assured.

A single electronic device which employs electron conduction in a vacuum, gas or semiconductor is not regarded as a high-integrity part.

~~Compliance~~ Conformity with 7.3 is checked by inspection of component manufacturers data or by performing the relevant tests.

~~8.4 Connection to telecommunication networks~~

~~IEC 62151 shall be used for ports intended to be connected to telecommunication networks.~~

7.4 Connection to other equipment

Where equipment is intended to be electrically connected to another product, to an accessory, or to a ~~communication circuit~~ wired network port, interconnection circuits shall be selected to provide continued performance to the requirements of Table A.1. This is normally achieved by connecting ELV circuits to ELV circuits, SELV circuits to SELV circuits, PELV circuits to PELV circuits, PEB circuits to PEB circuits and TNV circuits to TNV circuits. For definitions and information on TNV circuits, refer to IEC 62151. Interconnecting cables can carry more than one type of circuit (SELV circuit, TNV circuit, ELV circuit, hazardous voltage circuit, etc.) provided that they are separated as required by this document. It is possible that HLV circuits ~~may~~ be connected to other HLV circuits of other equipment which have compatible electrical ratings.

~~Compliance~~ Conformity with 7.4 is checked by inspection.

Where additional products are specifically complementary to the host (first) equipment (for example, a separate control interface for the equipment), ELV circuits are permitted as interconnection circuits between these items, provided that these continue to meet the requirements of this document when connected together.

7.5 ~~Laser~~ High-intensity light sources

Equipment using high-intensity light sources – for example fibre optic interfaces – shall be designed in accordance with IEC 60825-1.

7.6 Explosion

7.6.1 General

For information on components not covered by 7.6, see 7.3 and Annex D.

7.6.2 Components at risk of explosion

7.6.2.1 General

When components liable to explode if overheated or overcharged are not provided with a pressure-release device, protection for the user shall be incorporated in the equipment (see 4.10.4.5).

Pressure-release devices shall be located such that a discharge will not cause ~~danger~~ a hazard to the user. The construction shall be such that any pressure-release device ~~shall~~ is not ~~be~~ obstructed.

7.6.2.2 Batteries

Batteries shall not cause explosion or produce a fire hazard as a result of excessive charge or discharge or if installed with incorrect polarity. Where necessary, protection shall be incorporated in the equipment, unless the manufacturer's instructions specify that it is for use only with batteries which have built-in protection. See Annex F for examples of battery protection circuits.

If an explosion or fire hazard could occur through fitting a battery of the wrong type (for example, where a battery with built-in protection is specified), there shall be a warning marking (see 8.1.10) on or near the battery compartment or mounting and a warning in the manufacturer's instructions. An acceptable marking is symbol 14 of Table 12 (refer to documentation from the manufacturer).

If the equipment has means for charging rechargeable batteries, and if non-rechargeable cells could be fitted and connected in the battery compartment, there shall be a warning marking in or near the compartment (see 8.1.8 and 8.1.10).

The battery compartment shall be designed so that there is no possibility of explosion or fire caused by build-up of flammable gases. Batteries shall be so mounted that safety cannot be impaired by leakage of their electrolyte.

For batteries intended to be replaced by the user, if an attempt is made to install a battery with its polarity reversed, no hazard shall arise.

Conformity is checked by inspection, including inspection of battery data, to establish that failure of a single component cannot lead to an explosion or fire hazard. If necessary, a short circuit and an open circuit are made on any single component (except the battery itself) whose failure could lead to such a hazard.

8 Marking, documentation and packaging

8.1 Marking

8.1.1 General

When mounted in its normal operating position, the equipment should carry, where possible, markings in accordance with 8.1.2 to 8.1.11 inclusive. These markings shall, where possible, be visible from the exterior of the equipment or be visible by removing a cover or the opening of an aperture without the aid of a tool, if the cover or aperture is intended to be removed by the user.

Where, because of space limitations, it is not possible for these markings to be visible in the normal operating position or they are found elsewhere on the equipment, an explanation of these symbols shall be included in the ~~equipment~~ documentation (see Table 12 for the description of the symbols).

Where a hazard exists, the caution symbol 14 of Table 12 and associated hazard symbol shall be displayed as close as possible to the hazard, for example caution symbol and high voltage symbol placed on terminal block. If general warnings are needed, the caution symbol 14 of Table 12 shall be used and the meaning of this shall be detailed in the documentation. **15**

For rack or panel equipment, markings are permitted to be on any surface that becomes visible after removal of the equipment from the rack or panel.

Markings that apply to the whole equipment shall not be placed on parts that can be removed by the user without the use of a tool.

~~For the values of preferred voltages, currents, frequency and their tolerances, IEC 60255-1 should be referred to.~~

~~Safety marking shall wherever possible take precedence over any functional markings.~~

The values of preferred voltages, currents, frequency and their tolerances should be as specified in IEC 60255-1.

The markings listed in Clause 8 shall be considered to be safety-related.

8.1.2 Identification

The equipment shall, as a minimum, be marked with:

- the name or trademark of the manufacturer or supplier;
- the model or type reference;

- if equipment bearing the same distinctive designation (model number) is manufactured at more than one location, the manufacturing location (factory location can be in code).

~~The above are the minimum mandatory requirements that shall be marked on the equipment.~~ If the equipment consists of two parts, the part accessible under normal ~~conditions~~ use shall be marked with type and manufacturer. The other part should have all markings in accordance with 8.1.

~~Compliance~~ Conformity with 8.1 shall be checked by inspection.

8.1.3 Auxiliary supplies, ~~VT, CT, I/O (Input/Output)~~ measurands, inputs and outputs

8.1.3.1 General requirements for marking

For marking, the following shall be taken into account:

- AC – with symbol 2 of Table 12 and rated frequency or frequency range;
- DC – with symbol 1 of Table 12;
- symbol 3 of Table 12 on equipment for AC and DC supply;
- symbol 4 of Table 12 on equipment for 3 phase AC supply;
- a hyphen (-) shall be used to separate the lower and upper ~~nominal~~ rated voltages ~~and~~ measurands, for example, 125 V-230 V;
- for selectable voltage or current markings:
 - the lower and upper selectable values shall be separated by means of a solidus, forward slash (/), for example, 125 V/230 V, 1 A/5 A;
 - when equipment uses voltages or frequencies where switching is automatic then the markings shall be according to symbol 15 of Table 12 or the word "AUTO" (see the examples in Table 12);
 - where an operating voltage is achieved using an external, separate device, for example, an additional series resistor, then the equipment shall be marked with this operating voltage followed by the legend +EXT.R. (in capital letters), for example, 125 V+EXT.R;
- the burden in watts (active power) or volt-amperes (apparent power) or the rated input current, with all accessories or plug-in modules connected;
- the documentation shall specify the burden of individual digital inputs, output relays and other I/O ports of significant burden in order for the user to calculate the worst-case burden for the equipment application;
- the values shall be measured with the equipment powered at ~~nominal~~ rated voltage, but without being operational; the measured value shall not exceed the marked value by more than 10 %;
- the rated supply voltage(s) or the rated supply voltage range.

If the equipment can be used on more than one voltage range then the separate voltage ranges shall be marked unless their maximum and minimum values do not differ by more than 20 % of the mean value.

If a user can set different rated supply voltages on the equipment then a means of indication for the set voltage shall be provided on the equipment. If AC or DC supply setting alteration can be achieved without the use of a tool, then the action of changing the setting shall also change the indication.

8.1.3.2 Auxiliary supply

The following information shall be provided:

- on the equipment and in the documentation:
 - AC and/or DC supply;

- the rated values;
- in the documentation:
 - the burden;
 - the operating voltage range (in accordance with IEC 60255-1).

8.1.3.3 Measurands

The following information shall be provided:

- on the equipment and in the documentation:
 - the ~~nominal~~ rated values, for example, voltage, current, frequency;
- in the documentation:
 - the burden;
 - the operating voltage range (in accordance with IEC 60255-1);
 - the overload withstand.

8.1.3.4 Inputs

The following information shall be provided:

- in the documentation:
 - AC and/or DC supply;
 - the rated values;
 - the burden.

NOTE For optical LPIT the rated values are the rated primary current for the optical LPIT input.

8.1.3.5 Outputs

The following information shall be provided:

- in the documentation:
 - the kind of output type, for example, ~~relay, optocoupler~~ normally open contact, change-over contact, etc;
 - ~~burden on the supply input;~~
 - ~~the characteristics of~~ the contact performance in accordance with IEC 60255-1.

~~Compliance~~ Conformity with 8.1.3.1 to 8.1.3.5 is checked by inspection or by measurement.

8.1.4 Fuses

Where a replaceable equipment fuse is used, the fuse rating and type (for example, the indication of rupturing speed) shall be marked adjacent to the fuse and details provided in the user manual. If the fuse is soldered into the printed circuit board, or there is not sufficient space on the board, then fusing details ~~may~~ shall be provided in the user manual only.

Rupturing speed codes of IEC 60127-1 ~~should~~ shall be used; see Table 11.

Table 11 – Fuse types

Fuse type	Identification
very quick-acting	FF or black
quick-acting	F or red
medium time lag	M or yellow
time lag	T or blue
long time lag	TT or grey

The recommended ratings of protective fuses or other external protective devices necessary to ensure that the equipment is safe under single fault conditions shall be detailed in the equipment installation and technical documentation.

~~Compliance~~ **Conformity** with 8.1.4 shall be checked by inspection.

8.1.5 Measuring circuit terminals

Marking shall be adjacent to the measuring terminals. Where there is insufficient space (as in multi-port equipment), it is permissible for the marking to be on the rating plate or for the terminal to be marked with symbol 14 of Table 12.

Where space permits, voltage and current terminals of measuring circuits shall be marked with the rated maximum working voltage or current as applicable, otherwise symbol 14 of Table 12 shall be used.

If there is a direct risk of electric shock due to accidental contact, for example terminal access does not comply with protective type ~~IP1X~~ IP2X (or better) according to 5.1 of IEC 60529:1989, ~~Amendment 1:1999~~, then symbol 14 and/or 12 of Table 12 shall be used.

~~Unless the equipment is clearly marked that it is not intended to be connected to voltages above 33 V a.c. or 70 V d.c. with respect to earth, then the voltage and current input circuit terminals accessible to the user shall be marked with the rated voltage to earth.~~

A permitted exception is where circuit terminals are dedicated to specific terminals of other equipment, which are provided with a means of identity. An example is a measuring circuit interconnection between two protective ~~equipments~~ **devices**.

~~Compliance~~ **Conformity** with 8.1.5 shall be checked by inspection.

8.1.6 Terminals and operating devices

Where necessary for safety, an indication using words, numbers or symbols shall be given of the purpose of all terminals, connectors, controls and indicators, including any operating sequences. Where there is insufficient space, it is permissible to use symbol 14 of Table 12. In such cases, the relevant information shall be provided in the equipment documentation.

AC or DC supply input connection terminals shall be identifiable.

Other markings of terminals and control devices should be adjacent to or on the terminal, but preferably ~~should not be~~ on any part which can be removed without the aid of a tool. The markings apply to the following:

- functional earth terminals with symbol 5 of Table 12;
- protective conductor terminals with symbol 6 of Table 12.

If the protective conductor terminal is part of a component (for example, terminal block) or subassembly and there is insufficient space, then it ~~may~~ **should** be marked with symbol 5 of Table 12.

Marking should not be indicated on easily changeable fixtures such as screws. Where the power and earth connections are provided by a plug ~~or~~ socket device, there is no requirement to mark the earth connection adjacent to such a device.

Circuit terminals designed to be accessible, floating at a voltage which is not hazardous live, are permitted to be connected to a common functional earth terminal or system (for example, a co-axial screening system). This terminal shall be marked with symbol 7 of Table 12, if this connection is not self-evident.

If the equipment contains ~~lasers or~~ high-intensity ~~infra-red diodes~~ light sources of class 2 rating or higher, and the output of these can be viewed under normal ~~conditions use~~ or maintenance ~~conditions use~~, then the equipment shall be marked ~~in accordance with IEC 60825-1~~ with symbol 16 of Table 12.

~~Compliance~~ **Conformity** with 8.1.6 shall be checked by inspection.

8.1.7 Equipment protected by double or reinforced insulation

Equipment protected throughout by double or reinforced insulation shall be marked with symbol 11 of Table 12, unless this equipment is provided with a protective conductor terminal or if a functional earth connection (for example, via cable screen) can be made to the equipment, under normal ~~conditions use~~.

Equipment which is only partially protected by double or reinforced insulation shall not bear symbol 11 of Table 12. ~~Basic insulation is acceptable in the terminal area of insulation class II equipment if it is accessed only under maintenance conditions.~~

~~Compliance~~ **Conformity** with 8.1.7 shall be checked by inspection.

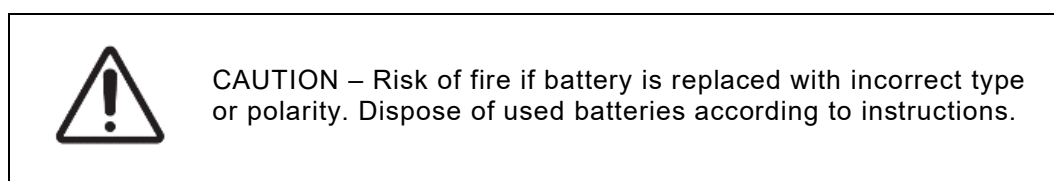
8.1.8 Batteries

8.1.8.1 Replaceable batteries

If the equipment has replaceable batteries and the replacement of these by an incorrect type of battery could result in an explosion (for example, in the case of certain types of lithium batteries) then:

- if a user can access the battery, there shall be a marking close to the battery or a statement in both the operating instructions and ~~servicing~~ **commissioning maintenance** instructions;
- if the battery is elsewhere in the equipment, marking is required; this shall be close to the battery or in a statement included in the ~~servicing~~ **commissioning maintenance** instructions.

The marking or statement shall be similar to the following.



It is permissible, where space is limited on the equipment, to use symbol 14 of Table 12.

The polarity of the battery shall be marked on the equipment unless it is not possible to insert the battery with incorrect polarity.

8.1.8.2 Charging

Equipment which has facilities for the recharging of ~~internal~~ batteries where non-rechargeable cells could be fitted and connected in the battery compartment shall be marked in or near to this compartment, warning against the charging of non-rechargeable batteries. This warning shall also indicate the type of rechargeable battery that shall be used within the recharging circuit.

Where space does not permit, this information shall be provided in the equipment documentation. In such cases, it is preferred that symbol 14 of Table 12 be adjacent to the battery.

~~Compliance~~ Conformity with 8.1.8.1 and 8.1.8.2 is checked by inspection.

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Table 12 – Symbols

Number	Symbol ^b	Publication Symbol reference	Description
1		IEC 60417-5031:2002-10	Direct current
2		IEC 60417-5032:2002-10	Alternating current
3		IEC 60417-5033:2002-10	Both direct and alternating current
4		IEC 60417-5032-1:2002-10	Three-phase alternating current
5		IEC 60417-5017:2006-08	Earth ~~terminal~~ ; ground
6		IEC 60417-5019:2006-08	Protective ~~conductor terminal~~ earth; protective ground
7		IEC 60417-5020:2002-10	Frame or chassis ~~terminal~~
8		IEC 60417-5021:2002-10	Equipotentiality
9A		IEC 60417-5007:2002-10	On (~~Supply~~ Power)
9B		IEC 60417-5008:2002-10	Off (~~Supply~~ Power)
10		IEC 60417-5010:2002-10	On/ or Off (~~Supply~~ push-push)
11		IEC 60417-5172:2003-02	~~Equipment protected throughout by double insulation or reinforced insulation (equivalent to class II of IEC 61140)~~ Protective Class II equipment
12 ^a		IEC 60417-6042:2010-11	Caution, risk of electric shock
13 ^a		IEC 60417-5041:2002-10	Caution, hot surface
14 ^a		ISO 7000-0434B:2004-01	Caution, ~~refer to documentation~~ ^c
15		ISO 7000-0017:2004-01	~~230/110 V AUTO~~ ~~or~~ ~~230/110 V~~ Automatic control (Closed loop)

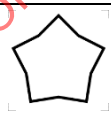
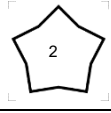
Number	Symbol ^b	Publication Symbol reference	Description
16		IEC 60417-5152:2002-10	Radiation of laser apparatus
^a ~~IEC 60417 should be referred to for warning symbol dimensions.~~ ^a Colour requirements for symbols 12, 13 and 14 do not apply to markings on equipment provided that the symbol is moulded or engraved to a depth or raised height of 0,5 mm or that the symbol and outline are contrasting in colour with the background. ^b Warning symbol dimensions should be as specified in IEC 60417. ^c Caution symbol is a general warning and means refer to documentation for full details of hazard.			

8.1.9 Test voltage marking

The symbols indicated in Table 13 shall be used for marking of the test voltage(s) if the manufacturer chooses to mark the equipment.

Table 13 – Symbols for marking of test voltage(s)

Dielectric test voltage	Symbol
Test voltage 500 V	
Test voltage above 500 V (for example, 2 kV)	
Impulse test voltage	Symbol
Test voltage 1 kV	
Test voltage 5 kV	

Number	Symbol	Publication	Description
1		IEC 60417-5179:2002-10	Test voltage (Dielectric), 500 V
2		IEC 60417-5179:2002-10 modified to show higher dielectric voltage	Test voltage (Dielectric) above 500 V (Example shown 2 kV)
3		IEC 60417-5179-1:2009-08	Test voltage impulse, 1 kV
4		IEC 60417-5179-1:2009-08 modified to show higher impulse voltage	Test voltage impulse above 1 kV (Example shown 5 kV)

8.1.10 Warning markings

In general, for rack-mounted or panel-mounted equipment, markings are permitted on any surface that becomes visible after removal of the equipment from the rack or panel. Markings should not be on the bottom of the equipment, except on hand-held equipment or where space is limited.

This is also applicable to the rear plate of rack-mounted or panel-mounted equipment where there is insufficient space for warning markings. Symbols 14 and/or 12 of Table 12 shall be used in this case, as close as possible to the rear plate.

Where access in normal use presents a risk of electric shock, the warning marking symbol 12 of Table 12 shall be used; this shall be visible either from the front panel or be visible after removing a cover or opening a door or flap without the aid of a tool.

If the user needs to refer to equipment documentation or instruction literature, then the equipment shall be marked with symbol 14 of Table 12.

The equipment documentation shall state that the equipment shall be isolated or disconnected from hazardous live voltage before access to potentially hazardous live-parts is affected.

Equipment having batteries shall be marked according to the requirements of 8.1.8.

The size of warning markings shall be as follows.

- Symbols shall be at least 2,75 mm high. Text shall be at least 1,5 mm high and contrast in colour with the background.
- Symbols or text moulded, stamped or engraved in a material shall be at least 2,0 mm high. If not contrasting in colour, they shall have a depth or raised height of at least 0,5 mm.

~~Compliance~~ Conformity with 8.1.9 and 8.1.10 shall be checked by inspection and measurement.

8.1.11 Marking durability

All markings shall remain clear and legible under conditions of normal use and shall resist the effects of cleaning agents as specified by the manufacturer. This shall also include the effect of natural or artificial light.

An adhesive that is permanent shall be used to secure adhesive labels.

~~After compliance testing these labels shall not have become loose nor shall the edges and corners curl.~~

~~Compliance shall be checked by inspection and by rubbing, by hand, without undue pressure:~~

- ~~• for 15 s with a cloth soaked with a cleaning agent(s) as specified by the manufacturer;~~
- ~~• if no agent is specified then with water.~~

Conformity shall be checked by performing the following test for durability of markings on the outside of the equipment. The markings are rubbed by hand, without undue pressure, for 30 s with a cloth soaked with each specified cleaning agent (or, if not specified, with 70 % isopropyl alcohol).

After the above treatment, the markings shall be clearly legible and adhesive labels shall not have worked loose or become curled at the edges.

8.2 Documentation

8.2.1 General

~~The equipment documentation shall clearly identify the equipment and include the name and address of the manufacturer or its agent. Information for safety shall be delivered with the equipment as a printed document.~~

~~The manufacturer shall provide, on request, documentation that includes the technical specification, instructions for commissioning and for the use of the equipment. Where relevant, the documentation shall cover any calibration, maintenance and subsequent safe disposal and decommissioning of the equipment and any of its replaceable parts.~~

The equipment documentation shall follow the documentation guideline in IEC 60255-1. The manufacturer shall supply, on request, documentation relating to equipment type tests and routine testing. The product safety instructions shall be included with the equipment in paper format. All other information may be supplied in electronic format. Where applicable, warning statements and a clear explanation of warning symbols marked on the equipment shall be included in the documentation. In particular, wherever symbol 14 of Table 12 is used, there shall be a statement to the effect that the documentation shall be consulted to establish the nature of any potential hazard and any actions which need to be taken to eliminate or minimize this hazard.

The documentation shall include the following:

- a statement that the integrity of any protective conductor connections shall be checked before carrying out any other actions;
- a statement that the equipment ratings, operating instructions and installation instructions shall be checked before commissioning or maintenance use;
- the information specified in 8.2.2 to 8.2.5;
- the intended use of the equipment.

8.2.2 Equipment ratings

8.2.2.1 General

The equipment documentation shall include the following:

- the installation category (overvoltage category) for which the equipment is intended (this is related to the ability of the equipment to withstand transient overvoltages);
- the supply voltage or voltage range, frequency or frequency range and power or current rating of the equipment;
- the permitted fluctuation from the ~~nominal~~ rated functional value ~~should also be stated~~, for example, the lower and upper ~~functional voltages~~ values of the voltage range;
- a description of all input and output connections.

8.2.2.2 Fuses and external protective devices

The type, current rating and voltage rating of any internal fuse shall be stated according to 8.1.4. This shall include fuses that ~~may~~ can or ~~may not~~ cannot be accessed by a user for replacement.

The recommended fuse type or other protective means shall take into account the switching capacity and interrupting speed.

The type, current rating and voltage rating of any external fuse or protective device required for safe operation of the equipment shall be given in the product documentation.

Where it is recommended that an external switch, circuit breaker or other protective device be connected near to the equipment, this shall be stated.

8.2.2.3 Environmental requirement

The equipment documentation shall state the following:

- the operating ambient temperature range;
- the maximum altitude it is designed to operate up to;
- the IP rating at the front of the equipment when it is mounted in its normal position of use;
- the impact test IK rating;
- the pollution degree for the equipment – for example, pollution degree 2 – when mounted in its normal position of use;
- the insulation class of the equipment – for example, Class I equipment – when mounted in its normal position of use.

Compliance Conformity with 8.2.1 to 8.2.2.3 is checked by inspection.

8.2.3 Equipment installation

For installation purposes, the equipment documentation shall include the following, as appropriate.

- Instructions relating to the safe mounting of the equipment shall be stated including any specific location and assembly requirements.
- Instructions relating to the protective earthing of the equipment shall be stated. This shall include a recommendation of the size of wire to be used and a statement indicating that protective earth connections ~~should~~ shall not be removed when the equipment is energized.
- Any special ventilation requirements shall be stated. This is related to the heat dissipated by the equipment.
- The manufacturer shall also indicate the maximum number or percentage of digital input circuits and output relays, which ~~may~~ can be energized simultaneously at the maximum ambient temperature.
- Wire type, size and rating necessary for correct installation and safety of the equipment shall be indicated.
- Information regarding the requirement for and the specification of any external devices required for the safe operation of the equipment, as in 8.2.2.2 shall be included.

Compliance Conformity with 8.2.3 is checked by inspection.

8.2.4 Equipment commissioning and maintenance

Equipment instructions concerning preventative maintenance and inspection shall be given in enough detail to ensure the safety of these procedures. Instructions shall include recommendations relating to safety earthing and de-energization of the equipment, where applicable.

The following shall also be included, where applicable.

- Instructions for fault-finding and repair, where applicable, shall be given to the extent that is relevant for operation and maintenance use.
- The manufacturer shall specify any parts, which shall only be examined or supplied by the manufacturer or the manufacturer's agent.
- The manufacturer shall specify the safe methods for changing and disposal of:
 - any accessible fuses including type and ratings as per 8.1.4;

- any replaceable batteries, for example, lithium, and/or suitable replacements where applicable;
- the method of safe recharging and/or replacement for rechargeable batteries with recommendation of suitable replacements where applicable;
- where ~~fibre-optic communication output devices~~ high-intensity light sources are fitted, warnings shall be given that these should not be viewed directly.

~~Compliance~~ Conformity with 8.2.4 is checked by inspection.

8.2.5 Equipment operation

Operating instructions for the equipment shall include the following.

- A requirement that before working on CT circuits, these shall be short-circuited.
- A statement indicating that it is the responsibility of the user to ensure that the equipment is installed, operated and used for its intended function in the manner specified by the manufacturer. Also that, if this is not the case, then any safety protection provided by the equipment ~~may~~ can be impaired.
- An explanation of, and where possible pictures of, symbols used on the equipment according to 8.1.

8.3 Packaging

The scope of this document does not cover the transportation of equipment between the manufacturer and the customer. However, the manufacturer shall ensure that the equipment is suitably packaged and labelled to withstand, without damage, reasonable handling and environmental conditions appropriate to the method(s) of transportation to the customer's delivery address.

~~A visual inspection should be made by the customer to check that the equipment has not been damaged during transportation.~~

9 Type tests and routine tests

9.1 General

~~Testing, as defined in this clause, is required to demonstrate that the equipment is fully in accordance with the safety requirements specified in this standard and also the manufacturer's claims.~~

Equipment shall be designed to meet the requirements of all relevant clauses of this document and tested to prove conformity where necessary. Type testing alone (as Table 14 type tests) does not form a complete safety assessment and does not guarantee that the correct components and materials have been used; this can only be achieved by assessment against all clauses of this document. **16**

Table 14 – Overview of tests

Test	Reference	Type tests ^b		Routine test ^c
		Validation ^a (informative)	Safety (normative)	
Environmental tests				
~~Dry heat test—operational~~	40.6.1.1	X	—	—
~~Cold test—operational~~	40.6.1.2	X	—	—
~~Dry heat test at maximum storage temperature~~	40.6.1.3	X	—	—

Cold test at minimum storage temperature	10.6.1.4	X	—	—
Damp heat test	10.6.1.5	X	—	—
Cyclic temperature with humidity	10.6.1.6	X	—	—
Vibration	10.6.2.1	X	—	—
Shock	10.6.2.2	X	—	—
Bump	10.6.2.3	X	—	—
Seismic	10.6.2.4	X	—	—
Reverse polarity and slow ramp	10.6.6	X	—	—
Safety-related tests				
Clearances and creepage distances	10.6.3	—	X	—
Accessible parts test	10.6.2.5	—	X	—
IP rating	10.6.2.6	—	X	—
Impulse voltage	10.6.4.2	—	X	—
AC or d.c. dielectric voltage	10.6.4.3	—	X	X
Insulation resistance	10.6.4.4	X	—	—
Protective bonding resistance	10.6.4.5	—	X	—
Protective bonding continuity	10.6.4.5.2	—	—	X
Flammability of insulating materials, components and fire enclosures ^d	10.6.5.2	—	X ^d	—
Single fault condition	10.6.5.5	—	X	—
Electrical environment tests				
Maximum temperature of parts and materials	10.6.5.1	X	—	—
Thermal short time	10.6.5.3	X	—	—
Output relay, make and carry	10.6.5.4	X	—	—

Test	Reference	Type tests ^{a,g} Safety (normative)	Routine test ^g
Environmental tests			
Dry-heat test – operational	9.6.1.2	X ^{c,e} 17	—
Cold test – operational	9.6.1.3	X ^{c,e}	—
Dry-heat test at maximum storage temperature	9.6.1.4	X ^e	—
Cold test at minimum storage temperature	9.6.1.5	X ^e	—
Damp-heat, steady state test	9.6.1.6	X ^{d,e}	—
Damp-heat, Cyclic	9.6.1.7	X ^{d,e}	—
Vibration	9.6.2.1	X ^f 18	—
Shock	9.6.2.2	X ^f	—
Bump	9.6.2.3	X ^f	—
Seismic	9.6.2.4	X ^f	—
Safety-related tests			
Leakage current	4.7	X	—
Clearances and creepage distances	9.6.3	X	—
Accessible parts test	9.6.2.5	X	—
IP rating	9.6.2.6	X	—
Impulse voltage	9.6.4.2	X	—

AC or DC dielectric voltage	9.6.4.3	X	X
Insulation resistance	9.6.4.4	X	—
Protective bonding resistance	9.6.4.5.1	X	—
Protective bonding continuity	9.6.4.5.2	---	X
Flammability of insulating materials, components and fire enclosures ^c	9.6.5.2	X ^b	—
Single fault condition	9.6.5.5	X	—
Reverse polarity and slow ramp	9.6.6	X	—
Resistance to mechanical stress	9.6.7	X	—
Marking durability	8.1.11	X	—
Electrical environment tests			
Maximum temperature of parts and materials	9.6.5.1	X	—
Thermal short time	9.6.5.3	X	—
Output relay, make and carry	9.6.5.4	X	—
^a ~~Validation tests are normally carried out as type tests during product development but they may have an impact on product safety. After validation testing, the equipment under test should be checked for compliance with safety requirements, for example, due to cracking or distortion of parts providing insulation.~~ ^a ~~Compliance~~ Conformity with type-test requirements may be carried out by testing, measurement, visual inspection or assessment, as appropriate. For example, clearance and creepage distance measurement (or visual inspection where the distances are obviously large) or technical argument such as assessment of single fault conditions where the result would be known. There shall be no electrical shock or fire hazard during or after conducting the normally applied type tests to demonstrate claimed ~~compliance~~ conformity. ^e ~~For sample test guidance, refer to 10.6.4.3.2.3.~~ ^b Testing of plastic parts may be necessary where the material does not meet the minimum flammability specified in Clause 6, or its thickness is below the minimum specified for that material to achieve the required minimum flammability. ^c The safety critical components shall be checked to ensure they remain within their operating temperature. This can be measured during the temperature tests or can be measured at room temperature and extrapolated. ^d Safety critical components shall be checked to ensure that insulation properties are maintained (this can be via testing of individual component or checking of manufacturer's data). ^e Upon completion of the tests the solid insulation shall be tested by application of the AC or DC dielectric voltage and insulation resistance test to prove it has not been compromised. ^f Upon completion of the tests the AC or DC dielectric voltage test and the impulse voltage test shall be carried out to prove that there is no degradation. ^g X: applicable; —: not applicable			

Single fault testing shall be carried out unless it can be demonstrated that it is improbable that a hazard ~~may~~ can arise from a ~~particular~~ single fault condition (see 4.10).

9.2 Safety type tests

Safety type tests are normative and carried out to verify that the equipment complies with the safety requirements of this document. Unless otherwise specified, safety type tests may be carried out in any appropriate sequence. A safety type test may be carried out on a pre-production sample or on different samples of the same type.

Unless otherwise agreed, safety type tests shall be performed on all equipment which has not previously been the subject of satisfactory safety type testing or which has been the subject of modifications which could affect the performance of the equipment.

Where certain details of the equipment are altered, the ~~particular~~ safety type test(s) whose results could be affected by the alterations shall be repeated.

The safety type test may be carried out by the manufacturer or an independent test house. The manufacturer shall provide the customer with access to documentary evidence of satisfactory results when required to do so.

Type testing a product which is part of a product family shall be considered sufficient to cover the entire product family provided a documented risk assessment is carried out to determine which type tests are valid and which tests need to be repeated on the rest of the product family.

An example risk assessment process is given in Annex G. **19**

9.3 Routine testing ~~or sample testing~~ **20**

~~It is normative to conduct either a routine test or a sample test to confirm that the equipment's design features for protection against electric shock have been maintained. Unless otherwise specified, these tests may be carried out in any sequence. (See 10.6.4.3.2.2 for further detail on routine testing and 10.6.4.3.2.3 for the necessary requirements for sample testing.)~~

A conformity test shall be conducted on each individual item during or after manufacture to confirm that the equipment's design features for protection against electric shock have not been compromised. Unless otherwise specified, these tests may be carried out in any sequence. See 9.6.4.3.2 for further detail on routine testing.

9.4 Conditions for testing

The type tests shall be performed under the ~~common~~ test reference conditions given in IEC 60255-1.

The following data for each test to be conducted shall be accessible from the manufacturer on request:

- the cross-sectional area and length of connecting cables, if these can affect the type test results for example, temperature rise;
- for vibration testing, details of cable terminations and looming, including the position of wire loom supports;
- measurement accuracy and tolerance permitted for all measurements.

Where applicable, the data shall include:

- initial measurement;
- measurement during the individual test;
- final measurement.

9.5 Verification procedure

The verification procedure shall ensure that the equipment is in accordance with its specification and that it functions correctly during the initial measurement at the beginning of the test sequence and maintains its design characteristics throughout all the following individual tests where this has been specified.

The order for testing is initial measurement, measurement during the individual test and final measurement.

The exception to this is after single fault condition testing where the only verification required is that the equipment does not pose a fire or electric shock hazard and that the dielectric withstand has not been compromised.

In a test sequence where the final measurement of the previous test corresponds to the initial measurement of the succeeding individual test, it is not necessary to do these measurements twice, once is sufficient.

The above measurements comprise a visual inspection and a functional test to ensure that the equipment is in accordance with its specification.

9.6 Tests

9.6.1 Climatic environmental tests

9.6.1.1 General

The purpose of the climatic environmental tests is to ensure the insulation and components are operating within their temperature range without degradation. The solid insulation is tested by the application of the AC or DC dielectric voltage test and impulse test.

9.6.1.2 Dry-heat test – operational

The dry-heat operational test shall be performed in accordance with IEC 60255-1 to prove the resistance of the equipment to heat, whilst operational.

9.6.1.3 Cold test – operational

The operational cold test shall be performed in accordance with IEC 60255-1 to prove the resistance of the equipment to cold, whilst operational.

9.6.1.4 Dry-heat test at maximum storage temperature

The dry-heat storage test shall be performed in accordance with IEC 60255-1 to prove the resistance of the equipment to storage heat.

9.6.1.5 Cold test at minimum storage temperature

The cold storage test shall be performed in accordance with IEC 60255-1 to prove the resistance of the equipment to cold storage.

9.6.1.6 Damp-heat, steady state test

To prove the resistance to humidity, the equipment shall be subjected to a damp-heat, steady state test in accordance with IEC 60255-1. The requirements of the test are also regarded as fulfilled if the equipment is composed of sub-assemblies, components and parts which have already passed this test in a comparable test combination. If necessary, a test of those sub-assemblies which have not yet been tested is sufficient.

9.6.1.7 ~~Cyclic temperature with humidity test~~ Damp-heat, cyclic

To prove the resistance to cyclic ~~temperature with humidity~~ damp-heat, the equipment shall be subjected to a cyclic temperature with humidity test in accordance with IEC 60255-1.

9.6.2 Mechanical tests

9.6.2.1 Vibration

To prove the robustness of the hardware design the equipment shall be subjected to vibration response and vibration endurance testing ~~according to IEC 60255-21-1~~ in accordance with IEC 60255-1 and shall be verified by the application of the AC or DC dielectric voltage test and the impulse voltage test. **21**

9.6.2.2 Shock

To prove the robustness of the hardware design the equipment shall be subjected to shock response and shock withstand testing ~~according to IEC 60255-21-2~~ in accordance with IEC 60255-1 and shall be verified by the application of the AC or DC dielectric voltage test and the impulse voltage test.

9.6.2.3 Bump

To prove the robustness of the hardware design the equipment shall be subjected to bump testing ~~according to IEC 60255-21-3~~ in accordance with IEC 60255-1 and shall be verified by the application of the AC or DC dielectric voltage test and the impulse voltage test.

9.6.2.4 Seismic

To prove the robustness of the hardware design the equipment shall be subjected to seismic testing ~~according to IEC 60255-21-3~~ in accordance with IEC 60255-1 and shall be verified by the application of the AC or DC dielectric voltage test and the impulse voltage test.

~~Compliance: there shall be no electrical shock or fire hazard during or after conducting the normally applied type tests to demonstrate claimed compliance with 10.6.2.1 to 10.6.2.4.~~

9.6.2.5 Accessible parts test

The purpose of this test is to verify that equipment cases, barriers or mounting panels prevent hazardous-live-parts being accessible in normal use.

This test, according to 4.3.3.2, shall be carried out as a type test for the equipment to verify that hazardous-live-parts cannot be accessed ~~by the standard jointed test finger in 6.2 of IEC 61010-1:2010~~ and that the test finger voltage or energy does not exceed the safe limits for normal use, ~~defined in 5.1.5.3.2.~~

~~10.6.2.6 Dust/water ingress protection~~

~~Unless otherwise agreed, tests shall be carried out to confirm that the equipment case meets the manufacturer's claimed IP class in normal use. The tests shall be in accordance with those specified in IEC 60529 for the equipment case class.~~

9.6.2.6 Degree of protection provided by the enclosure 22

The ingress protection shall be tested to confirm that the equipment case meets the manufacturer's claimed IP code in normal use. The tests shall be in accordance with those specified in IEC 60529:1989, IEC 60529:1989/AMD1:1999, IEC 60529:1989/AMD2:2013.

9.6.3 Clearances and creepage distances

~~Where there is any doubt~~ Unless otherwise determined – for example, from computer assisted design (CAD) data, drawing or inspection – that the required clearance and creepage distances are compliant with the values in the appropriate Annex C table, measurements shall be made. Where the minimum clearance value is not met, then the clearance may be proven by testing (see 4.9.2.2). Testing to prove the clearance in air cannot be used to demonstrate ~~compliance~~ conformity of the associated creepage distance.

Where a transient suppressor is used to reduce the overvoltage, the circuit shall be tested to show that it withstands the ~~application of 5 positive and 5 negative impulses from a source impedance of 2 Ω~~ surge test in accordance with IEC 60255-26 and that the transient suppression is adequately rated (not damaged). ~~Surge test generator characteristics and impulse voltage amplitude for a differential and/or common mode supply input according to IEC 60255-26 shall be used.~~

9.6.4 Safety-related electrical tests

9.6.4.1 General

The purpose of the voltage tests in 9.6.4.2 to 9.6.4.4 is to prove clearances and solid insulation.

The test voltage level shall be the open-circuit voltage of the generator before connection to the equipment.

9.6.4.2 Impulse voltage test

9.6.4.2.1 General

The impulse voltage type test is carried out with a voltage having a 1,2/50 μ s waveform (see ~~Figure 1 of IEC 61180-1:1992~~ IEC 61180) and is intended to simulate overvoltages of atmospheric origin. It also covers overvoltages due to switching of low-voltage equipment.

9.6.4.2.2 Test procedures

The impulse voltage test shall be carried out in accordance with the following.

The impulse voltage shall be applied to the appropriate points accessible from the outside of the equipment; the other circuits and the accessible conductive parts shall be connected together and to earth.

The tests for proving clearances shall be conducted for a minimum of three impulses of each polarity with an interval of at least 1 s between impulses.

The same test procedure also applies for proving the capability of solid insulation; however, five impulses of each polarity shall be applied in this case, and the wave shape of each impulse shall be monitored and failures recorded.

Both tests, for proving clearances and solid insulation, may be combined in one common test procedure.

9.6.4.2.3 Waveform and generator characteristics

A standard impulse voltage in accordance with ~~IEC 61180-1~~ IEC 61180 shall be used. ~~The generator characteristics shall be verified according to IEC 61180-2.~~ The parameters are detailed in Table 15.

Table 15 – Impulse generator characteristics

Parameter	Level
open-circuit voltage	~~1 or 5 kV $\pm$ 10 %~~ see tables in Annex C $\pm$ 10 %
front time	1,2 μ s $\pm$ 30 %
time to half-value	50 μ s $\pm$ 20 %
output impedance	500 Ω $\pm$ 10 %
output energy	0,5 J $\pm$ 10 %
test lead length	< 2 m

~~The length of each test lead shall not exceed 2 m.~~

9.6.4.2.4 Selection of impulse test voltage **23**

~~10.6.4.2.4.1 General~~

The applicable rated impulse test voltage shall be ~~selected from one of the following nominal values: 0, 1, 5 kV peak~~ at least the appropriate impulse voltage selected from the tables in Annex C. Alternatively the manufacturer can claim a higher level of rated impulse test voltage in which case that higher level shall be used for testing.

When zero-rated impulse test is specified for particular equipment circuits, these shall be exempt from the impulse voltage test.

~~The specified impulse test of 5 kV peak applies to altitudes up to 200 m. For altitudes above 200 m, Table C.11 shall be used to reduce the test voltage.~~

When the test is between two independent equipment circuits, the higher of the two rated impulse voltages shall be used for the test. Decoupling capacitors can provide a route for the impulse test voltage and produce an apparent test failure. In that case the test level should be stated in the user documentation.

~~10.6.4.2.4.2 Equipment to be tested at 5 kV peak nominal~~

~~An equipment circuit, classed as a primary circuit, according to Clause 3, shall be tested at 5 kV peak nominal, in accordance with 10.6.4.2.4.~~

~~10.6.4.2.4.3 Equipment to be tested at 1 kV peak nominal~~

~~Equipment circuits may be tested at 1 kV peak nominal, in accordance with 10.6.4.2.4, if the following apply.~~

- ~~• The auxiliary (power supply) circuits are connected to a battery used exclusively for the power supply of equipment covered by this standard. This battery shall not be used for switching inductive loads.~~
- ~~• The equipment is not powered via current or voltage transformers.~~
- ~~• I/O circuits required to be tested are not subjected to induced or inductive load transients in excess of 1 kV peak.~~

9.6.4.2.5 Performing of tests

The impulse voltage type test is applicable whether or not the equipment under test is fitted with surge suppression. If surge suppression devices are fitted these shall not be removed for the test.

Unless otherwise specified, the impulse voltage test shall be performed:

- between each circuit ~~(or each group of circuits) specified for the same impulse voltage~~ and the accessible conductive parts ~~at the impulse voltage specified for this circuit (or this group of circuits);~~
- between independent circuits, the terminals of each independent circuit being connected together;
- across the terminals of a given circuit to validate the manufacturer's claim.

Circuits specified for the same rated insulation can be grouped together.

Circuits not involved in the tests shall be connected together and to earth.

Unless obvious, the independent circuits are those which are so described by the manufacturer.

For equipment with an insulated case, the accessible conductive parts shall be represented by a metal foil covering the whole equipment case except the terminals around which a suitable gap shall be left so as to avoid flashover to the terminals. The test between two independent circuits shall be carried out, unless otherwise specified, at the higher impulse voltage specified for the two circuits.

9.6.4.2.6 Test acceptance criteria

There shall be no disruptive discharge (spark-over, flashover or puncture) during test. Partial discharges in clearances which do not result in breakdown are disregarded. After this type test, the equipment shall comply with all relevant performance requirements.

It is permissible for an impulse voltage waveform applied across test points connected to surge suppression, inductive devices or potential dividers, to be attenuated or distorted if this is not due to electrical breakdown.

The waveform applied to test points not connected to such devices, will not be noticeably distorted or attenuated unless the insulation does not withstand the impulse voltage test.

~~10.6.4.2.7 Repetition of the impulse voltage test~~ 24

~~For equipment in a new condition, impulse voltage tests may be repeated, if necessary, to verify performance. The test voltage value shall be equal to 0,75 times the value originally specified or indicated by the manufacturer.~~

9.6.4.3 AC or DC dielectric voltage test 25

9.6.4.3.1 Type testing

9.6.4.3.1.1 Performing the dielectric voltage test

Type tests shall be applied:

- between each circuit and the accessible conductive parts, the terminals of each independent circuit being connected together;
- between independent circuits, the terminals of each independent circuit being connected together.

Unless obvious, the independent circuits are those which are so described by the manufacturer. The test voltage for independent circuits shall be the higher requirement of the two independent circuits assessed.

Circuits specified for the same rated insulation voltage may be connected together when being tested to the accessible conductive parts.

If applicable, the manufacturer shall declare the dielectric voltage withstand, ~~for across~~ across open metallic contacts and verify this by type testing. ~~No test should be applied across contacts when transient suppression devices are fitted. Circuits not involved in the tests shall be connected together and to earth.~~

Circuits with transient suppression devices fitted across contacts shall be either tested using DC (both polarities) or shall have the transient suppression devices removed in order to perform the test. Circuits not involved in the tests shall be connected together and to earth.

The test voltages shall be in accordance with Annex C applied directly to the terminals.

For equipment with an insulating case, the accessible conductive parts shall be represented by a metal foil covering the whole equipment case except the terminals around which a suitable

gap shall be left so as to avoid flashover to the terminals. Insulation tests requiring this metal foil shall be performed as type tests only.

10.6.4.3.2.3 Routine tests by sampling

Sample testing of the assembled equipment may be carried out if the following points are met.

- The fully assembled printed circuit cards or modules are 100 % routine tested.
- The manufacturer has carried out a risk analysis and documented that, due to the design and build of the equipment, for all build variations, there is a very low probability of safety risks due to any build and handling problems, when the routine tested items are assembled into the equipment.
- Any sample testing is carried out to a documented sampling plan.

Sample tests on the assembled equipment shall be performed between the same circuits specified in 10.6.4.3.2.2.

The minimum number of samples, randomly chosen from the batch to be tested, shall be two.

The acceptance criteria for this safety test shall be: accept on zero failures, reject on one failure.

In the case of a batch rejection, the batch shall either be 100 % tested, or after investigation and rectification of the cause of failure, the batch may be retested to the documented sampling plan.

9.6.4.3.1.2 Value of the dielectric test voltage

Dielectric voltage tests shall be made by applying the appropriate voltages in Table 14. The test voltage should be declared by the manufacturer.

Table 14 — AC test voltages

Rated insulation voltage V	AC test voltage, 1 min. kV
Up to 63	0,5
125 to 500	2,0
630	2,3
800	2,6
1 000	3,0

The applicable dielectric withstand voltage shall be at least the appropriate dielectric withstand voltage selected from the tables in Annex C. Alternatively the manufacturer can claim a higher level of dielectric withstand voltage, in which case that higher level shall be used for testing.

For circuits directly energized via instrument transformers (~~VTs and standard CTs~~), or connected to a station battery, the test voltage shall not be less than 2,0 kV AC RMS, 1 min. Where this is not the case, ~~Table 14 may be used to determine the appropriate test voltage~~, see C.1.3 for the determination of the rated insulation voltage for circuits energized from various supplies.

A higher test voltage of 2,5 kV AC RMS for 1 min for CT circuits may be claimed by the manufacturer. Higher test voltages shall be specified for pilot wire circuits where short-circuit current induced overvoltages on the pilot wires are to be expected. The applicable test voltage shall, in this case, be declared by the manufacturer.

~~For commoned circuits such as CTs, VTs and digital inputs connected by a common connection to earth or neutral, a test voltage of 500 V may be used.~~ If applicable, the manufacturer shall declare the dielectric voltage withstand for open metallic contacts and verify this by type testing. ~~No test shall be applied across contacts when transient suppression devices are fitted.~~

9.6.4.3.1.3 Test voltage source

The test voltage source shall be such that, when applying half the specified value to the equipment under test, the voltage drop observed is less than 10 %.

The source voltage value shall be verified with accuracy better than ± 5 %.

The test voltage shall be substantially sinusoidal and at a frequency between 45 Hz and 65 Hz. ~~However, tests may alternatively be performed with a d.c. voltage (positive and negative polarity) the value of which shall be 1,4 times that given in Table 14.~~ Certain factors, for example, capacitors to earth for EMC-compliance conformity, will lead to increased test current and thus make detection of a breakdown condition difficult. This problem can be overcome by using a DC test voltage ($\sqrt{2} \times 1,4 \times \text{RMS}$) or by measuring AC resistive current only.

9.6.4.3.1.4 Test method

For type tests the open-circuit voltage of the test generator is applied to the equipment at zero volts. The test voltage shall be raised smoothly to the specified value in such a manner that no appreciable transients occur and shall be maintained for 1 min minimum. It shall then be reduced smoothly to zero as rapidly as possible.

For routine tests, the test voltage may be maintained for 1 s minimum. In this case, the test voltage shall be 10 % higher than the specified 1 min type test voltage.

9.6.4.3.1.5 Test acceptance criteria

During the dielectric voltage test, no breakdown or flashover shall occur. Partial discharges which do not cause the maximum test current level set by the manufacturer to be exceeded, shall be disregarded.

9.6.4.3.1.6 Repetition of the dielectric voltage test

For equipment in a new condition, dielectric voltage tests may be repeated, if necessary, to verify their performance. ~~The test voltage value shall be equal to 0,75 times the value claimed by the manufacturer.~~

9.6.4.3.2 Routine tests

Routine dielectric voltage tests shall be applied:

- between all independent circuits and the accessible conductive parts, the terminals of all independent circuits being connected together;
- between independent circuits, the terminals of all other independent circuits being connected together. If a risk assessment indicates that testing between particular independent circuits is not necessary, then the tests for those circuits may be omitted.

Guidance for routine ~~and sample~~ dielectric voltage testing for safety is provided in Table 16; ~~see 10.6.4.3.2.3 for testing to a sampling plan.~~

Table 16 – Guidance for routine ~~and sample~~ dielectric voltage testing for safety ~~— Informative~~

Risk	Probability	Routine test ^c		Sample test ~~Assemble d equipment~~
		Assembled board or module	Assembled equipment	
Manufacturing ~~and/or~~ design related issues typically due to: - solder bridging between PCB tracks ~~and/or~~ pads; - component leads either not cropped to the specified length or bent in the wrong direction; - component insulation failure; - solder resist or conformal coating badly applied to the PCB; - handling.	Medium	X ^{a,b}	X ^{a,b}	~~-----~~
Assembly issues – clearance reduced typically due to errors such as: - conductive component (heat sink, etc.) not correctly fitted; - fixing screw too long; - conductive instead of non-conductive parts used; - extraneous parts such as screws, nuts and wire offcuts.	Low	—	~~X^{b,c}~~ X ^b	~~X^{b,c}~~
^a Routine tests can be carried out on an assembled board ~~and/or~~ module, or on assembled equipment, or on both. ~~^b Routine or sample test as appropriate.~~ ^b All tests are 1 min at rated dielectric test voltage or for 1 s at 110 % rated dielectric test voltage. ^c X: applicable; —: not applicable				

9.6.4.4 Insulation resistance

The insulation resistance measurement ~~may~~ shall be performed ~~as a test following~~ in conjunction with environmental testing to ensure that the insulation has not been over-stressed and weakened by the applied tests, see Table 14.

The measuring voltage shall be applied directly to the equipment terminals:

- between each circuit and the accessible conductive parts, the terminals of each independent circuit being connected together;
- between independent circuits, the terminals of each independent circuit being connected together.

NOTE Insulation resistance measurement (circuit to ground) is not required for resistor divider arrangements.

The insulation resistance shall be determined when a steady value has been reached and at least 5 s after applying a DC voltage of 500 V ± 10 %.

~~For equipment in a new condition, The insulation resistance shall not be less than 100 MΩ at 500 V d.c. (A lower value may be used where EMC suppression or other functional components connected in parallel with the circuit under test may reduce the insulation resistance). After the damp-heat type test, the insulation resistance shall not be less than 10 MΩ at 500 V d.c., after a recovery time of between 1 h and 2 h, at reference ambient conditions.~~

The insulation resistance shall not be less than 1 MΩ at 500 V DC. After the damp-heat, steady state type test, the insulation resistance shall not be less than 1 MΩ at 500 V DC, after a recovery time of between 1 h and 2 h, at reference ambient conditions. **26**

9.6.4.5 Protective bonding tests

9.6.4.5.1 Protective bonding resistance – Type test

Accessible conductive parts and terminations connected to the protective conductor for protection against any electric shock hazard shall not have excessive resistance.

For equipment where the protective conductor connection is by means of one core of a multi-cored cable, the cable is not included in the measurement, provided that the cable is supplied by a suitably rated protective device which takes into account the size of the conductor.

The ~~compliance~~ conformity of such parts with protective bonding resistance type test requirements shall be determined using the following test parameters:

- the test current shall be twice that of the maximum current rating of the overcurrent protection means, specified in the user documentation, but not less than 20 A;
- the test voltage shall not exceed 12 V AC RMS or 12 V DC;
- the test duration shall be 60 s;
- the resistance between the protective conductor terminal and the part under test shall not exceed 0,1 Ω .

9.6.4.5.2 Protective bonding continuity – Routine test

Accessible conductive parts which ~~may~~ can become live in the event of a single fault condition shall be subject to a low current continuity test to verify their bonding to the protective conductor terminal.

~~It is recommended that~~ The continuity tester open-circuit voltage and short-circuit current should be chosen to avoid any circuit damage.

9.6.5 Electrical environment and flammability

9.6.5.1 Maximum temperature of parts and materials

~~Tests may be required to determine~~ The maximum temperature of parts and materials under normal use (see 6.3) and under a single fault condition (see 6.10) ~~may be determined by testing~~.

9.6.5.2 Flammability of insulating materials, components and fire enclosures

Testing of parts may be necessary where either the material does not meet the minimum flammability requirements specified in 6.6, or its thickness is below the minimum specified for that material to achieve the required minimum flammability.

Tests shall not be required to determine the flammability of insulating materials and components providing they meet the requirements of 6.6.2 to 6.6.4 and fire enclosures 6.9.

9.6.5.3 Thermal short-time test

9.6.5.3.1 Thermal overload 27

The maximum temperature of the insulating materials, during the following tests, shall be within the limits given for the appropriate insulation class in Table 8.

Overvoltage

a) Voltage input:

The equipment voltage input circuits shall withstand overvoltages declared by the manufacturer, without ~~damage, both continuously and for 10 s duration~~ creating any safety hazard, for both continuous and for 10 s overvoltage levels.

Overcurrent**b) Current input:**

The equipment current input circuits shall withstand continuous and 1 s duration rated overcurrents declared by the manufacturer, ~~both continuously and for 1 s duration, without creating a fire or electric shock risk~~, without creating any safety hazard or exceeding any component rating. The effectiveness of insulation shall be tested by:

- measuring the temperature of insulating materials to ensure that they stay within their operating range during the tests; or
- performing the dielectric and insulation resistance after tests to ensure the insulation has not been damaged.

However, the manufacturer shall only state safe withstand values.

Safety requirements for protection equipment, with CTs rated between 0,5 A and 5 A are as follows:

- 1) minimum 1 s overcurrent withstand ~~should~~ shall be 100 ~~in~~ times the rated current;
- 2) continuous withstand ~~should~~ shall be at least ~~4 in~~ four times the rated current.

For protection equipment and measuring relays which do not meet these requirements, the manufacturer shall declare the overcurrent withstand and continuous withstand.

~~For CTs with no declared rated current value, for example, sensitive earth fault, the continuous and 1 s overcurrent withstand for safety shall be declared by the manufacturer.~~

9.6.5.3.2 Short time limiting dynamic overload 28

The purpose of the short time limiting dynamic overload test is to check if a relay withstands the resulting electromagnetic forces from high currents without being damaged electrically or mechanically. Additional information can be found in IEC 61869-2. The equipment CT input circuits (conventional CT inputs) shall withstand limiting dynamic overcurrents for 0,5 cycle of rated power frequency with:

- no electrical safety and fire hazard risks;
- conformity with dielectric strength requirements before and after the test

Safety test requirements for protection equipment, with CTs rated 1 A and 5 A are given in Table 17.

Table 17 – Limiting dynamic values

Rated current (RMS)	Frequency	Thermal withstand (RMS) 100 × rated current		Limiting dynamic value (peak) 250 × rated current	
		Value	Duration	Value	Duration
1 A	16,7 Hz	100 A	1 s	250 A	30 ms
5 A	16,7 Hz	500 A	1 s	1 250 A	30 ms
1 A	25 Hz	100 A	1 s	250 A	20 ms
5 A	25 Hz	500 A	1 s	1 250 A	20 ms
1 A	50 Hz	100 A	1 s	250 A	10 ms
5 A	50 Hz	500 A	1 s	1 250 A	10 ms
1 A	60 Hz	100 A	1 s	250 A	8,3 ms
5 A	60 Hz	500 A	1 s	1 250 A	8,3 ms

9.6.5.4 Output relay parameters

The manufacturer shall test the output trip relay ~~parameters~~ (including PCB track, terminal block, etc. connected to the output trip relay) to ensure performance ~~is~~ meets the minimum requirements in accordance with IEC 60255-1 or the equipment manufacturer's published specification (if greater) except for parameters guaranteed by the relevant component manufacturer's specification.

9.6.5.5 Single fault condition

Refer to 4.10 for single fault condition assessment and 6.10.3 for ~~compliance~~ conformity with the requirements for protection against the spread of fire when conducting a single fault type test on fully assembled equipment. It is sufficient to carry out a single fault test(s) on a particular module variation, once only, where the common module is used throughout a platform range. After the single fault, the dielectric testing shall be performed to ensure that the solid insulation has not been compromised.

The need for any single fault testing will depend on the result of the single fault condition assessment.

9.6.6 Reverse polarity and slow ramp test

The manufacturer shall test the power supply inputs to ensure that reverse application of the supply voltage does not cause ~~excessive internal temperatures~~ any safety critical component to achieve a temperature outside its rated operating temperature at the equipment's maximum rated ambient temperature, spread of fire or risk of electrical shock. The assessment of fire risks shall be determined using methods of 6.10. The supply voltage shall be applied reverse polarity for ~~sufficient time~~ at least 1 min to enable thermal equilibrium to be achieved for all safety critical components. This test is applicable for DC powered products only.

The manufacturer shall test the power supply inputs to ensure that slow variations in supply voltage do not cause ~~excessive internal temperatures~~ any safety critical component to achieve a temperature outside of its rated operating temperature at the equipment's maximum rated ambient temperature, spread of fire or risk of electrical shock or damage of the product. The supply voltage shall be varied in accordance with Figure 4, ~~the internal temperatures~~, and the safety critical components of the power supply shall be monitored to ensure that ~~excessive temperatures are not seen~~ no safety critical component achieves a temperature outside of its rated operating temperature at the equipment's maximum rated ambient temperature during the test. During the testing, the equipment under test shall be in a quiescent state with half the binary inputs ~~and~~ outputs energized and communications ports exercised (where fitted). The supply voltage shall be varied with a defined gradient for ramp down ~~and~~ ramp up of 1 V/min in accordance with Figure 4. This test is applicable for DC powered products only.

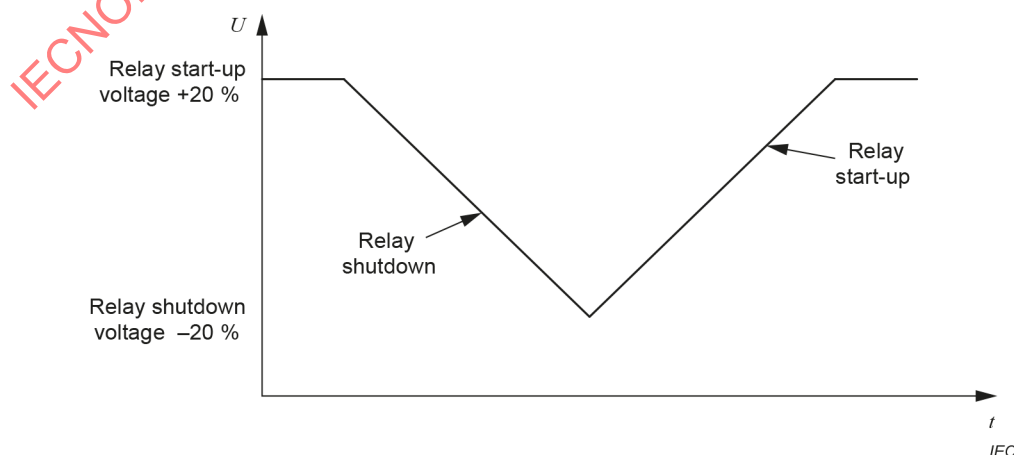


Figure 4 – Voltage ramp test

9.6.7 Resistance to mechanical stress **29**

9.6.7.1 General

Equipment shall not cause a hazard when subjected to mechanical stresses likely to occur in normal use.

The normal energy protection level required is at least IK6 (1 J) (based on IEC 61010-1) provided that all the following criteria are met.

- a) When the equipment is installed in its intended application it cannot easily be touched by unauthorized persons.
- b) In normal use, the equipment is only accessed for occasional operations such as adjustment, programming or maintenance.

Conformity is checked by inspection and by performing each of the following tests on the parts of the enclosure accessible under normal use:

- 1) the static test of 9.6.7.2;
- 2) the impact test of 9.6.7.3 at the energy level specified above.

Parts which do not form part of an enclosure are not subjected to the tests of 9.6.7.2 and 9.6.7.3.

After the tests, visibly damaged windows and displays shall be inspected to check that hazardous-live-parts have not become accessible. In addition the equipment shall be inspected to check that:

- there have been no leaks of corrosive or harmful substances;
- enclosures show no cracks which could cause a hazard;
- clearances are not less than their permitted values;
- the insulation of internal wiring remains undamaged;
- protective barriers necessary for safety have not been damaged or loosened;
- no moving parts are exposed;
- there has been no damage which could cause spread of fire.

9.6.7.2 Static test

The equipment is held firmly against a rigid support and subjected to a force of 30 N applied by the hemispherical end of a hard rod of 12 mm diameter. The rod is applied to each part of the enclosure which could easily be touched when the equipment is ready for use.

In case of doubt whether a non-metallic enclosure will pass this test at an elevated temperature, this test is performed after the equipment is operated at the maximum rated ambient temperature, until a steady-state condition is reached. The equipment is disconnected from the supply source before the test is performed.

9.6.7.3 Impact test

Covers, etc., intended to be removed and replaced by an operator have their fixing screws tightened using a torque likely to be applied in normal use. With the equipment held firmly against a rigid support, the impact is applied to all points on surfaces which are easily touched in normal use and which would be likely to cause a hazard if damaged.

NOTE A support is considered to be sufficiently rigid if its displacement is less than or equal to 0,1 mm under the effect of an impact directly applied and whose energy corresponds to the degree of protection.

Non-metallic enclosures of equipment with a minimum rated ambient temperature below 2 °C are cooled to the minimum rated ambient temperature, then tested within 10 min.

If an enclosure is damaged by an impact but meets the pass criteria, a new enclosure may be used for the next impact.

Fixed equipment is mounted as specified in the installation instructions. Other equipment is held firmly against a rigid support and each test point is subjected to one impact by a smooth steel sphere with a mass $500\text{ g} \pm 25\text{ g}$ and with a diameter of approximately 50 mm.

The impact test can be performed using the method shown in Figure 5 a) or Figure 5 b).

Figure 5 a) shows the impact applied to a horizontal surface, with the sphere allowed to fall freely from a height of 200 mm. The equipment can be mounted at 90° to its normal position to allow this method to be used.

Figure 5 b) shows the impact applied to a vertical surface, with the sphere suspended by a cord and allowed to fall as a pendulum through a vertical distance of 200 mm.

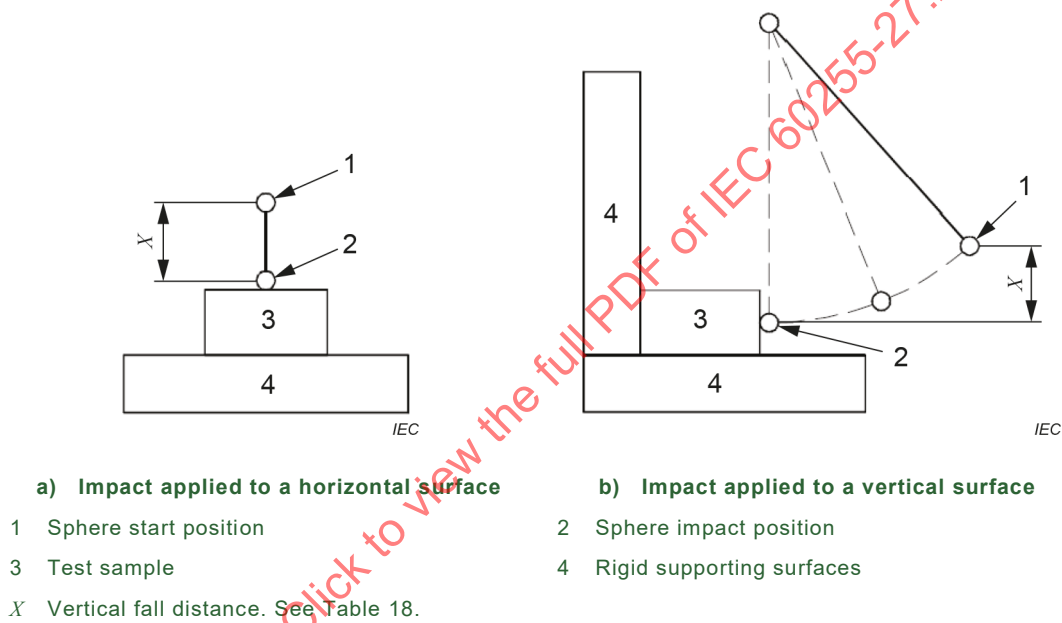


Figure 5 – Impact test with sphere

Table 18 – Impact energy levels, test height and corresponding IK codes

	Impact energy level (J) and IK code		
	1 (IK06)	2 (IK07)	3 (IK08)
Vertical fall distance, X (mm)	200	400	1 000

Annex A (normative)

Isolation class requirements and example diagrams

A.1 Introduction

A.1 General

This Annex A provides guidance on the isolation class and insulation requirements for different circuit types, with typical insulation examples. The isolation requirements, in conjunction with reference to 6.7 of IEC 61010-1:2010 and of IEC 61010-1:2010/AMD1:2016, and Annex B of IEC 61010-1:2010, ~~should~~ shall be used to determine the required clearances and creepage distances from Annex C.

ELV, PEB, PELV and SELV circuits provide protection from electric shock from hazardous live voltages and are not necessarily related to protective class I, II or III equipment class.

A.2 Hazardous live voltage (HLV)

Hazardous live voltage applies to the following:

- voltage transformers, current transformers, output relays;
- connection to the AC or DC supply;
- analogue and digital inputs ~~and~~ and outputs exceeding ~~33 V r.m.s. a.c. or 70 V d.c.~~ 30 V AC RMS or 60 V DC.

Table A.1 – Circuit isolation class for product circuits and/or groups

Circuit isolation class	Product circuits and/or groups
ELV Extra low voltage	Non-primary circuits complying with the following under normal ~~conditions~~ use: • not exceeding ~~33 V r.m.s. a.c. or 70 V d.c.~~ 30 V AC RMS or 60 V DC, below ELV voltage limits; • separated from HLV by at least basic insulation. See Figure A.4. ELV circuits should not be accessible under normal ~~conditions~~ use. Examples are: • non-primary circuits; • analogue and/or digital inputs and outputs, complying with ELV voltage limits; • connections to ELV terminations of other products.

Circuit isolation class	Product circuits and/or groups
SELV Safety extra low voltage	Non-primary circuits complying with ELV voltage limits and the following conditions: - separated from HLV by reinforced ~~/~~ or double insulation; - there ~~shall be~~ is no provision for an earth connection. See Figure A.1. SELV circuits may be accessible and are safe to touch under both normal and single fault conditions. Connection of an earth to a SELV circuit is not permitted; for example, connection to an earthed cable screen or earthed ~~communication circuit~~ wired network port is not permitted. Where this is required, the circuit definition should change in accordance with Figure A.2 (PELV). An exception could be for a PELV system earthed at one end of a cable run; it would be permissible to connect a SELV system at the other end. Examples are: - analogue and/or digital inputs and outputs which ~~may~~ can be connected direct to unearthed ~~communication networks or circuits~~ wired network port; - SELV ports which are suitable for connection to SELV ports of other products.
PELV Protective extra low voltage	Non-primary circuits complying with ELV voltage limits and the following conditions: ~~PELV circuits shall be~~ separated from HLV by reinforced ~~/~~ or double insulation; ~~PELV circuits may be~~ connected to functional earth, the protective (earth) conductor, or have provision for an earth connection. See Figure A.2. PELV circuits may be accessible and are safe to touch under both normal and single fault conditions. Examples are: - Analogue and/or digital inputs and outputs which ~~may~~ can be connected direct to ~~communication networks or circuits~~ wired network port; - PELV ports which are suitable for connection to PELV ports of other products.
PEB Protection by equipotential bonding	Non-primary circuits complying with ELV voltage limits and the following conditions: - basic protection against electric shock is provided by basic insulation separating HLV from PEB circuits; - for fault protection, PEB circuits and accessible conductive parts, ~~shall be~~ are bonded to the protective conductor terminal and ~~shall~~ comply with 9.6.4.5.1, which will prevent hazardous live voltages in PEB circuits. See Figure A.3. PEB circuits may be accessible and are safe to touch under both normal and single fault conditions. PEB circuits may be considered as protective earthed circuits or earthed accessible parts for the purposes of Table A.2. Examples are: - analogue and/or digital inputs and outputs which ~~may~~ can be connected direct to ~~communication networks or circuits~~ wired network port and LPVT, LPIT, LPCT connections; - PEB ports which are suitable for connection to PEB ports of other products.
Functional earth	Non-primary circuits complying the following conditions: - separated from ELV, PEB and PELV circuits by at least functional insulation; - separated from parts at hazardous voltage in the equipment by either: - double insulation or reinforced insulation; or - a protectively earthed screen or another protectively earthed conductive part, separated from parts at hazardous voltages by at least basic insulation. It is permitted to connect the functional earthed circuit to a protective conductor terminal or to a protective bonding conductor.
The symbols of this table are explained in Clause A.3.	

A.3 Symbols

The following symbols are used in Table A.1 and Figure A.1 to Figure A.4.

a) Requirements

B: basic insulation or supplementary insulation

D: double insulation or reinforced insulation

F: functional insulation

b) Circuits and parts

A: accessible part, not bonded to the protective conductor terminal

C: equipment case

ELV: circuit or part for which, under normal ~~conditions~~ use, the ELV voltage limits in Table A.1 are not exceeded

HLV: circuit or part that is hazardous live under normal ~~conditions~~ use, as defined in 3.22

PEB, PELV, SELV: circuits that are safe to touch under both normal and single fault conditions, as defined in Table A.1

Z: impedance of secondary circuit.

Table A.2 – Insulation requirement between any two circuits

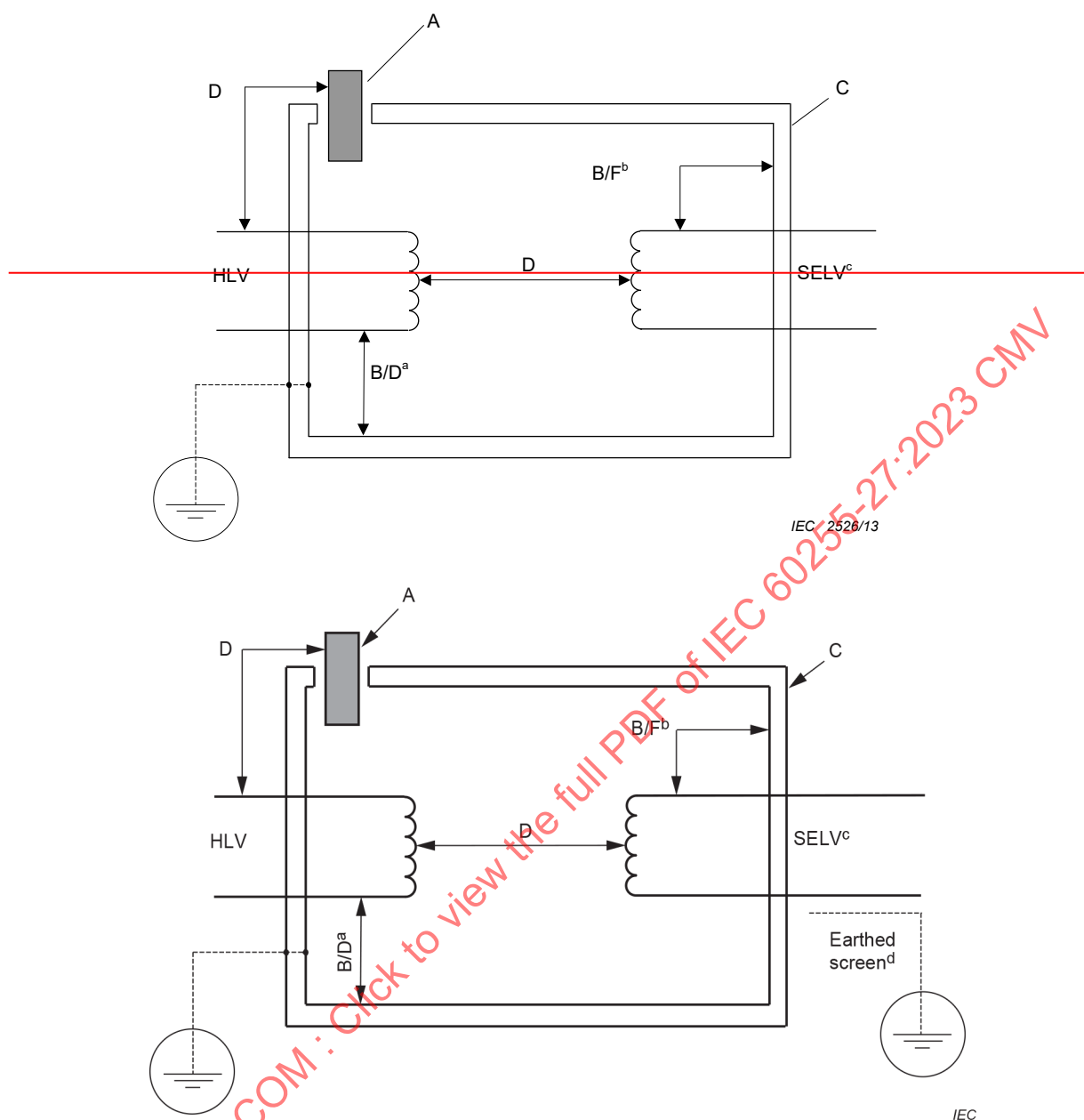
	HLV primary circuit ^a	ELV circuit	SELV circuit	PELV circuit	PEB circuit ^b	Protective earthed HLV non-primary circuit ^{b,c}	Unearthed HLV non-primary circuit ^c
HLV primary circuit^a	F/B ^{a,f} (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)	B ^e (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)
ELV circuit	B (Table C.4 – to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^{e,f} (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)
SELV circuit	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	F/B ^h (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)
PELV circuit^b	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	F/B ^h (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7))	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)

	HLV primary circuit ^a	ELV circuit	SELV circuit	PELV circuit	PEB circuit ^b	Protective earthed HLV non-primary circuit ^{b,c}	Unearthed HLV non-primary circuit ^c
PEB circuit ^b	B ^e (Table C.4 to Table C.7)	F/B ^{e,f} (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^e (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)
Protective earthed HLV non-primary circuit ^{b,c}	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)
Unearthed HLV non-primary circuit ^c	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)
Unearthed accessible parts ^g	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	B/D ^d (Table C.4 to Table C.7) / (Table C.7 to Table C.10)
Protective earth ^{b,g} / Protective earthed accessible parts ^{b,g}	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)

	HLV primary circuit ^a	ELV circuit	SELV circuit	PELV circuit	PEB circuit ^b	Protective earthed HLV non- primary circuit ^{b,c}	Unearthed HLV non- primary circuit ^c
The symbols are explained in Clause A.3. See Clause A.2 for typical circuit insulation requirements. Table C.2 to Table C.11 are shown in brackets in Table A.2. The choice of these tables depends on the overvoltage category and the pollution degree. ~~B = Basic insulation; D = Double or reinforced insulation; F = Functional insulation; S = Supplementary insulation~~ ^a If the functional voltage (not relative to earth) is greater than the rated insulation voltage, the creepage distance for the functional insulation may be greater than that of the basic insulation. One example is a terminal block where the functional phase to phase voltage is 400 V AC RMS. For a comparative tracking index (CTI) of 100 to 399, the creepage distance for 400 V functional insulation is 4,0 mm (Table C.3) compared with 3,0 mm (Table C.7) for 230 V AC RMS phase to ground (300 V basic insulation). ^b Connections to the protective conductor shall comply with 9.6.4.5.1; otherwise, this shall be considered to be an unearthed circuit. ^c There shall be at least basic insulation between HLV non-primary circuits and HLV primary circuits. ^d Insulation between an unearthed non-primary circuit at hazardous voltage and an unearthed accessible conductive part (B/D in Table A.2) shall satisfy the more onerous of the following: • double<del> or</del> reinforced insulation, the working voltage of which is equal to the hazardous voltage; or • supplementary insulation, the working voltage of which is equal to the voltage between the non-primary circuit at hazardous voltage; and – another non-primary circuit at hazardous voltage; or – a primary circuit. ^e See Figure A.3 for the conditional use of basic insulation for PEB. ^f Supplementary or basic insulation shall be used if one of the circuits is an independent circuit or is adjacent to a conductive part which ~~may be~~ is earthed when the equipment is installed. The insulation requirement will depend on the overvoltage category. The normal overvoltage category for equipment is overvoltage category III (Table C.6 or Table C.7); however, in some applications, where transients are limited to overvoltage category II, Table C.4 or Table C.5 may be applied if the equipment is supplied from one of the following: • a battery* with no protective relays or measuring equipment connected; or • the AC* supply of an office environment. * The maximum transient voltage amplitude on the supply shall be 2 500 V_{peak}. ^g A functional earthed circuit shall be treated as an unearthed accessible part. The exception is where the functional earth is bonded to the protective conductor and this meets protective bonding resistance requirements, then it may be treated as an earthed accessible part. ^h For a PELV system earthed at one end of a cable run, it would be permissible to connect a SELV system at the other end.							

A.4 Typical insulation examples complying with the requirements of Table A.2

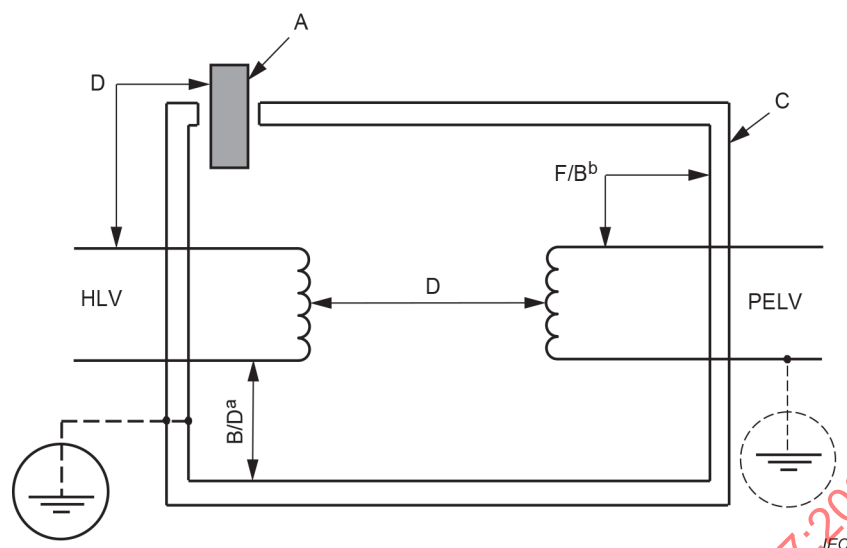
Refer to Table A.2 for the insulation requirements between different circuits and/or parts.



The symbols are explained in Clause A.3.

- ^a If the case and/or accessible parts are conductive and connected to the protective conductor terminal, only basic insulation (B) is required between these and HLV. Otherwise, double insulation (D) is required between case and/or accessible parts and HLV.
- ^b If the case is conductive, basic insulation (B) shall be used between it and the SELV circuit; otherwise, functional insulation (F) may be used.
- ^c Connection of an earth to a SELV circuit is not permitted.
- ^d If the SELV is screened cable then the outer screen can be connected to earth provided the screen and SELV circuit are separated by basic insulation.

Figure A.1 – Equipment with SELV input and/or output (I/O)

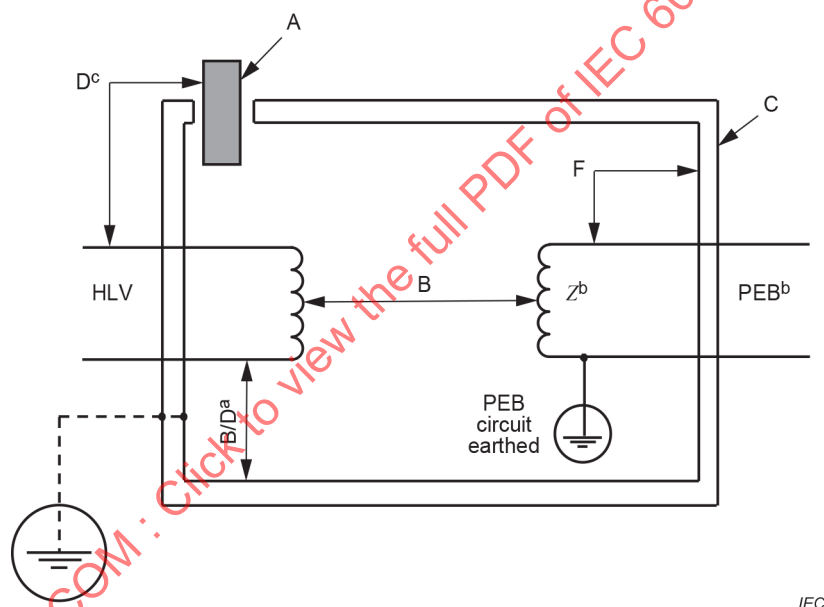
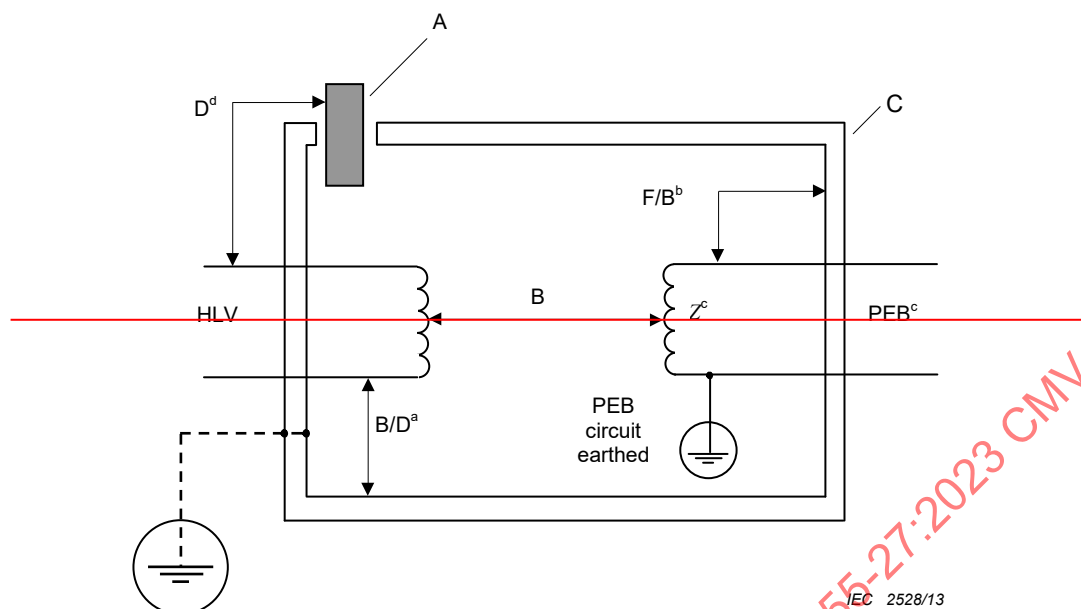


The symbols are explained in Clause A.3.

It is only permissible to connect an earth conductor to class II equipment for functional^a or EMC purposes, for example, an earthed cable screen; however, this screen shall be protected from adjacent circuits by basic insulation, rated for the adjacent circuit voltage.

- ^a If the case and/or accessible parts are conductive and connected to the protective conductor terminal, only basic insulation (B) is required between these and HLV parts. Otherwise, double insulation (D) is required between case and/or accessible parts and HLV parts.
- ^b If the case is conductive and unearthed, basic insulation (B) shall be used between it and the PELV circuit; otherwise, functional insulation (F) may be used.

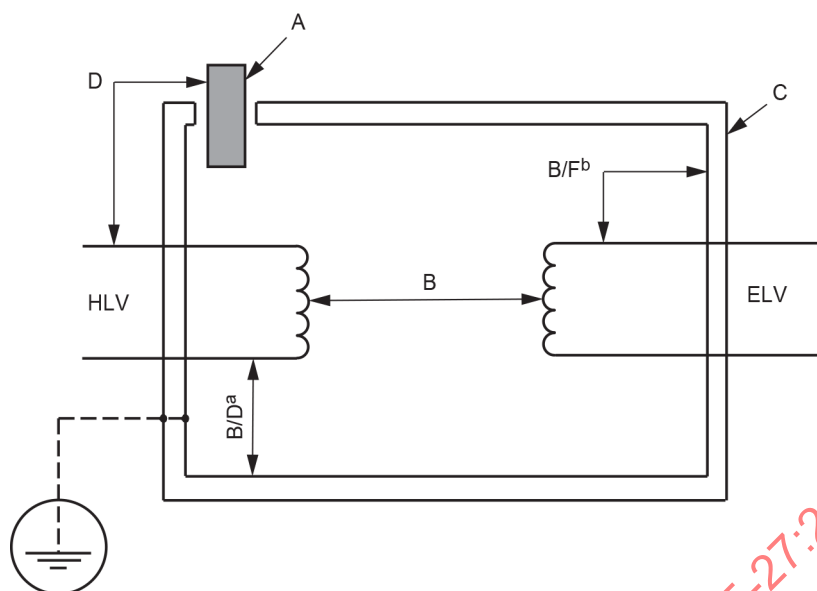
Figure A.2 – Equipment with PELV input and/or output (I/O)



The symbols are explained in Clause A.3.

- ^a If the case and/or accessible parts are conductive and connected to the protective conductor terminal, only basic insulation (B) is required between these and HLV parts. Otherwise, double insulation (D) is required between case and/or accessible parts and HLV parts.
- ~~^b If the case is conductive and unearthed, basic insulation (B) shall be used between it and the PELV circuit; otherwise, functional insulation (F) may be used.~~
- ^b The connection path of the PEB circuit to the protective conductor terminal, including impedance Z, shall comply with 9.6.4.5.1. Then, if under a single fault condition, an HLV conductor was shorted to the PEB circuit, the PEB circuit would not become hazardous live.
- ^c If the case and/or accessible parts are non-conductive, there shall be double insulation (D) between HLV circuits and/or parts and the applied rigid test finger (IEC 61010-1:2010, Figure B.1).

Figure A.3 – Equipment with PEB input and/or output (I/O)



IEC

The symbols are explained in Clause A.3.

- ^a If the case and/or accessible parts are conductive and connected to the protective conductor terminal, only basic insulation (B) is required between these and HLV parts. Otherwise, double insulation (D) is required between case and/or accessible parts and HLV parts.
- ^b If the case is conductive, basic insulation (B) shall be used between it and the ELV circuit; otherwise, functional insulation (F) may be used.

Figure A.4 – Equipment with ELV input and/or output (I/O)

Annex B (normative)

Rated impulse voltages

The purpose of this Annex B is to provide information on the withstand requirements for voltage impulses, which ~~may~~ can appear on the supply lines, relative to neutral and/or earth. The ~~nominal~~ rated supply or working voltages can be determined using 6.7 of IEC 61010-1:2010 and of IEC 61010-1:2010/AMD1:2016.

The relevant rated voltage and overvoltage category are used, together with the pollution degree, to select the appropriate table in Annex C for the determination of clearances and creepage distances, for safety reasons. For most applications 300 V and overvoltage category III are applicable (see C.1.2).

The impulse voltages for non-conventional input transformers are specified in IEC 61869-6, IEC 61869-10 and IEC 61869-11. Applicable insulation requirement for LPIT inputs of the protection equipment shall be checked from Table A.2 and test voltages from Table C.2 to Table C.11.

The rated impulse voltage determines the clearance in air.

Table B.1 – Rated impulse voltages (waveform: 1,2/50 µs)

Voltage line to neutral derived from ~~nominal~~ rated or working voltages AC RMS or DC up to and including ^{a,b} V	Rated impulse voltage ^c V		
	Overvoltage category		
	I	II	III ^d
50	330	500	800
100	500	800	1 500
150	800	1 500	2 500
300	1 500	2 500	4 000
600	2 500	4 000	6 000
1 000	4 000	6 000	8 000

^a The line to neutral voltages are preferred values (see IEC 61010-1:2010 and IEC 61010-1:2010/AMD1:2016, Annex K) for application to existing different low-voltage supplies and their ~~nominal~~ rated voltages.

^b The rated impulse voltages are given for an altitude of 2 000 m; see Table C.12 for the multiplication factor for the test voltage at higher altitudes.

^c Interpolation of the rated impulse voltage is not permissible for circuits connected to primary circuits.

^d Overvoltage category IV values are given in IEC 60664-1:2007/2020, Annex B.

Annex C (normative)

Guidance for the determination of clearance, creepage distance and withstand voltages

C.1 General

C.1.1 Introductory remark

This Annex C provides guidance for the determination of the minimum clearances, creepage distances and withstand voltages for equipment insulation, including the effect of altitude.

Clearances and creepage distances shall be selected after consideration of the following influences:

- pollution degree;
- overvoltage category;
- rated insulation voltage;
- insulation requirement (functional, basic, double and reinforced);
- location of insulation (for example, subject to mechanical stresses, etc.).

Basic insulation provides basic protection against electric shock and is normally determined for the working voltage relative to earth, for the appropriate overvoltage category, which determines the impulse voltage rating.

Functional insulation is required for the functioning of the equipment and does not provide protection against electric shock. The impulse voltage generally has little influence in the determination of functional insulation; Table C.3 or Table C.2 is normally appropriate. However, other tables, for example, Table C.4 to Table C.7, may be appropriate according to the transient or impulse voltages which ~~may~~ can be seen across the functional circuit. Therefore, Table C.4 to Table C.7 ~~may be~~ is applicable to functional insulation or basic insulation or supplementary insulation.

~~There are no~~ The clearance ~~or~~ and creepage distance requirements for the interior solid insulation of void-free moulded parts, including the inner layers of multi-layer printed circuit boards, ~~are detailed in IEC 61010-1~~. Solid insulation shall be proven by dielectric voltage testing in accordance with 9.6.4.3 or checked by measurement of the insulation thickness and inspection of the manufacturer's specifications.

The minimum creepage distance shall not be less than the minimum clearance in air. These clearance and creepage distances are minimum values; manufacturing tolerances shall additionally be taken into account.

C.1.2 Rated insulation voltages

The rated insulation voltage of one or all of the equipment's circuits can be determined from the tables in this Annex C. However, for equipment energized direct from instrument transformers and for circuits to be connected direct to the station battery supply, the rated insulation voltage shall not be less than 250 V; this is applicable for energizing voltages between 0 V and 250 V. If a 24 V or 48 V battery was used for communication purposes only, for example with no measuring relays or protection equipment connected to the battery supply, then according to Table C.1, 50 V is the appropriate working voltage and the associated impulse voltage for overvoltage category III is $800 V_{peak}$. However, IEC 62151 shall be used to determine if a higher overvoltage relevant to connection to a ~~communication~~ wired network ~~port~~ is applicable.

The rated impulse voltage of equipment energized direct from the low-voltage AC supply shall be selected from Table B.1 corresponding to the overvoltage category (normally III) specified and the ~~nominal~~ rated voltage of the equipment.

For basic, supplementary, reinforced and double insulation, the voltage values in column 1 of Table C.4 to Table C.11 are relative to earth and/or neutral (Table C.2 and Table C.3 are specifically for the working voltage of functional insulation and may not be relative to earth and/or neutral).

The rated insulation for non-conventional input transformers is specified in IEC 61869-6, IEC 61869-10 and IEC 61869-11. Applicable insulation requirement for LPIT inputs of the protection equipment shall be checked from Table A.2 and test voltages from Table C.2 to Table C.11.

C.1.3 Determination of rated insulation voltage

The rated insulation voltage shall be determined as follows:

- a) for insulation between live parts and accessible conductive parts, not less than the rated voltage of the circuit under consideration;
- b) for insulation between the parts of one circuit, except as provided in item e), not less than the rated voltage of the circuit under consideration;
- c) for insulation between parts of two independent circuits, the rated insulation voltage should be at least equal to the higher rated voltage of these circuits;
- d) for gaps between open contacts, unless otherwise agreed between manufacturer and user, no rated insulation voltage is specified;
- e) for circuits of an equipment having rated voltages exceeding 1 000 V, Annex A of IEC 60664-1:2007/2020 shall be used for determining clearances, creepage distances and withstand voltages.

The rated insulation voltage shall be determined from ~~6.7 of IEC 61010-1:2010~~ IEC 60664-1, with reference to C.1.2 of this document for the minimum applicable rating for some circuits.

C.1.4 Determination of rated impulse voltage

C.1.4.1 General

Transient overvoltages as expected during operation are taken as the basis for determining the rated impulse voltage (see 4.9.2.2 for primary circuits and 4.9.2.3 for non-primary circuits, and for the test reference).

Firstly, the rated insulation voltage shall be determined, see C.1.3.

The rated insulation voltage and applicable overvoltage category shall then be used in Table B.1 to determine the rated impulse voltage.

C.1.4.2 Selection of rated impulse voltage

The rated impulse voltage of equipment shall be determined using 6.7 of IEC 61010-1:2010/AMD1:2016 and Table B.1 of this document corresponding to the overvoltage category specified and to the ~~nominal~~ rated voltage of the equipment.

C.1.4.3 Impulse voltage insulation coordination within the equipment

For parts or circuits within the equipment which are significantly influenced by external transient overvoltages, the rated impulse voltage of the equipment applies. Transient overvoltages which can be generated by the operation of the equipment shall not influence external circuit conditions beyond that specified in C.1.5.

For other parts or circuits within the equipment which are specifically protected against transient overvoltages, by transient suppression, so that they are not significantly influenced by external transient overvoltages, the impulse voltage withstand required for insulation is not related to the rated impulse voltage of the equipment but to the actual conditions for that part or circuit and the clearance shall be determined from the appropriate Table C.2 to Table C.11. The transient protected circuit shall however comply with the test requirements in 9.6.3. However, the overall overvoltage category of the circuit cannot be reduced unless suitable transient suppression is employed for both differential and common modes.

C.1.5 Switching overvoltages generated by equipment

For equipment capable of generating an overvoltage at its terminals, for example switching devices, the rated impulse voltage implies that the equipment shall not generate overvoltages in excess of this value when used in accordance with the relevant standard and instructions of the manufacturer. Otherwise, the user shall provide measures to limit the impact of the switching overvoltages.

C.1.6 Insulation material

Comparative tracking index (CTI) values are used to categorize insulation materials as specified in Table C.1.

Table C.1 – Comparative tracking index (CTI)

Material group	CTI range
I	$600 \leq \text{CTI}$
II	$400 \leq \text{CTI} < 600$
IIIa	$175 \leq \text{CTI} < 400$
IIIb	$100 \leq \text{CTI} < 175$

For inorganic insulating materials, for example, glass or ceramics which do not track, creepage distances need not be greater than their associated clearances. However, the risk of disruptive discharge should be considered.

C.1.7 Overvoltage categories

The applicable overvoltage category shall be determined based on the following criteria.

a) Category I

This category applies to equipment where special measures are taken to limit transient voltages to appropriate values, for example, well-protected electronic circuits. To claim category I, the special voltage measures should apply to both common and differentially connected circuits.

b) Category II

~~Where all of the following apply:~~

This category applies to some cases of the application of equipment and shall be used where:

- 1) the auxiliary energizing circuits (power supply circuits) of the equipment are connected to a voltage supply used only for the power supply of static equipment. This is only the case if the leads are short and there is an absence of switching of other circuits connected to the AC or DC supply. The levels of transient voltage on the supply leads will be lower than specified in overvoltage category III;
- 2) the input energizing circuits of the equipment are not connected direct to voltage or current transformers, and good screening and earthing is employed on the connection leads;

3) the output circuits are connected to a load by short lead lengths.

c) Category III

This category applies to most practical cases of the application of equipment and shall, ~~in particular,~~ be used where:

- 1) the auxiliary energizing circuits (power-supply circuits) of the equipment are connected to a common battery and/or, due to long lead lengths, common mode transient overvoltages of a relatively high value ~~may~~ can appear on the supply leads, and differential mode voltages ~~may~~ can arise from switching in other circuits connected to the same battery or supply source;
- 2) the input energizing circuits of the equipment are connected to current and voltage transformers;
- 3) the output circuits are connected to a load by long leads with the result that common mode transient voltages of a relatively high value ~~may~~ can appear at the output terminals.

C.2 Determination of clearances, creepage distances and withstand voltages

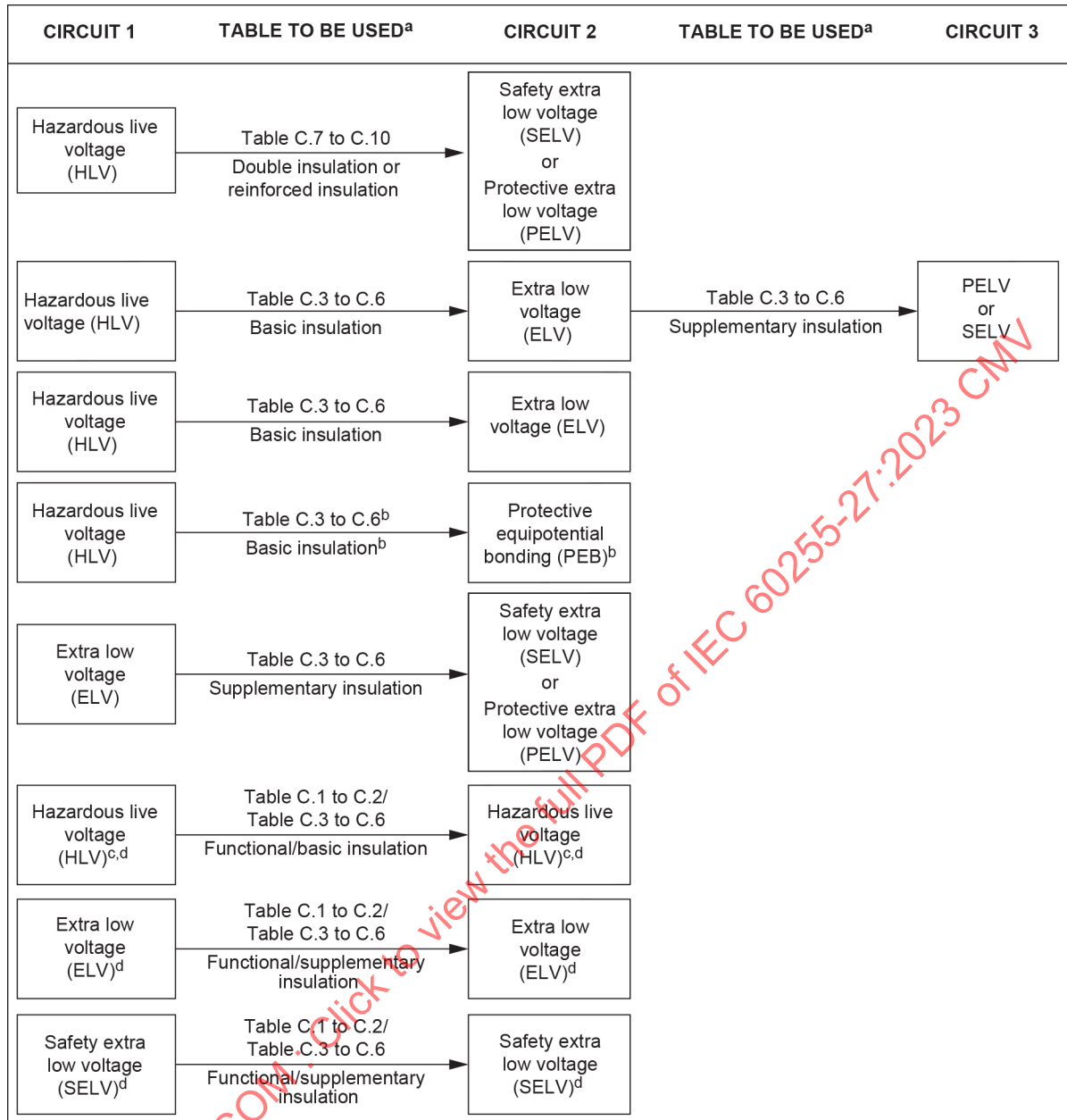
C.2.1 Guidance for determination of clearances, creepage distances and withstand voltages

See Figure C.1.

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~~CIRCUIT 1~~	~~TABLE TO BE USED^a~~	~~CIRCUIT 2~~	~~TABLE TO BE USED^a~~	~~CIRCUIT 3~~
~~Hazardous live voltage (HLV)~~	~~Table C.7 to C.10 Double insulation or reinforced insulation~~	~~Safety extra low voltage (SELV)^e~~	~~Protective extra low voltage (PELV)~~	
~~Hazardous live voltage (HLV)~~	~~Table C.3 to C.6 Basic insulation~~	~~Extra low voltage (ELV)~~	~~Table C.3 to C.6 Supplementary insulation~~	~~PELV or SELV~~
~~Hazardous live voltage (HLV)~~	~~Table C.3 to C.6 Basic insulation~~	~~Extra low voltage (ELV)~~		
~~Hazardous live voltage (HLV)~~	~~Table C.3 to C.6^b Basic insulation^b~~	~~Protective equipotential bonding (PEB)^b~~		
~~Extra low voltage (ELV)~~	~~Table C.3 to C.6 Supplementary insulation~~	~~Safety extra low voltage (SELV)^e~~	~~Protective extra low voltage (PELV)~~	
~~Hazardous live voltage (HLV)^{c,d}~~	~~Table C.1 to C.2/ Table C.3 to C.6 Functional/basic insulation~~	~~Hazardous live voltage (HLV)^{c,d}~~		
~~Extra low voltage (ELV)^d~~	~~Table C.1 to C.2/ Table C.3 to C.6 Functional/supplementary insulation~~	~~Extra low voltage (ELV)^d~~		
~~Safety extra low voltage (SELV)^d~~	~~Table C.1 to C.2/ Table C.3 to C.6 Functional/supplementary insulation~~	~~Safety extra low voltage (SELV)^d~~		

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^a Select the tables according to overvoltage category and pollution degree.

^b Provided that the PEB circuit cannot become hazardous live (see Figure A.3).

^c If the functional voltage (not relative to earth) is greater than the rated insulation voltage, the creepage distance for the functional insulation may be greater than that of the basic insulation. One example is a terminal block where the functional phase to phase voltage is 400 V AC RMS. Adhere to the minimum clearance for rated 4 kV peak impulse for 300 V basic insulation, but use Annex B of IEC 60664-1:2007/2020 to determine creepage distance for functional phase to phase voltage.

^d Supplementary or basic insulation (Table C.4 to Table C.7) shall be used if one of the circuits is an independent circuit, for example, where a withstand of 2 kV AC RMS for 1 min is required, by specification, between the two circuits.

^e ~~SELV: Safety extra low voltage is also known as separated extra low voltage.~~

Figure C.1 – Guidance for determination of clearances, creepage distances and withstand voltages

C.2.2 Determination of clearances, creepage distances and withstand voltages

C.2.2.1 General

Where the equipment is intended for pollution degree 3 or pollution degree 4 environments, Annex F of IEC 60664-1:2007/2020 shall be used to determine clearance and creepage distance requirements. A suitable enclosure in which to house the equipment may be required to ensure compliance conformity with pollution degree 3 or pollution degree 4 requirements.

C.2.2.2 Reduction of the pollution degree of the internal environment

For reduction of the pollution degree of the internal equipment environment, for external equipment environments of pollution degree 2 and pollution degree 3, see Table C.13.

C.2.2.3 Printed circuit board (PCB) coatings

The creepage distance values in Table C.3 to Table C.11 for coated (solder resist) PCBs shall only be used where the coating between the conductors covers one or both conductors and at least 80 % of the distance over the surface between them. The coating shall meet the requirements for type A 1 coatings given in IEC 60664-3.

Table C.2 – Functional insulation, pollution degree 1, overvoltage category I

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category I					
	Creepage distance mm		Clearance mm	Withstand voltage ^b V		
	In equipment CTI ≥ 100	On printed ^a wiring circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,18	0,05 0,025	0,05 0,01	330	230	330
100	0,25	0,10	0,10 0,04	500	350	500
150	0,30 0,31	0,25 0,22	0,15 0,10	800	490	700
300	0,70	0,70	0,50	1 500	820	1 150
600	1,70 1,68	1,70 1,68	1,50	2 500	1 350	1 900
1 000	3,20	3,20	3,00	4 000	2 200	3 100

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For proving the clearance in air, see 10.6.3 and Table C.11. For altitude correction to be applied, see Table C.12.

Table C.3 – Functional insulation, pollution degree 2, overvoltage category I

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category I								
	Creepage distance mm					Clearance mm	Withstand voltage ^c V		
	In equipment			On printed ~~wiring~~ circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	0,60	0,85	1,20	~~0,10~~ 0,04	~~0,05~~ 0,025	~~0,05~~ 0,20	330	230	330
100	~~0,70~~ 0,71	1,00	1,40	0,16	0,10	~~0,10~~ 0,20	500	~~350~~	500
150	~~0,75~~ 0,79	~~1,05~~ 1,09	~~1,50~~ 1,57	~~0,40~~ 0,36	~~0,25~~ 0,22	~~0,15~~ 0,20	800	490	700
300	1,50	2,10	3,00	~~1,50~~ 1,43	0,70	0,50	1 500	820	1 150
600	3,00	4,30	6,00	~~3,00~~ 3,04	~~1,70~~ 1,68	1,50	2 500	1 350	1 900
1 000	5,00	~~7,00~~ 7,10	10,00	5,00	3,20	3,00	4 000	2 200	3 100

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b See C.2.2 for minimum coating requirements.

^c ~~For proving the clearance in air, see 10.6.3 and Table C.11.~~ For altitude correction to be applied, see Table C.12.

Table C.4 – Functional, basic or supplementary insulation, pollution degree 1, overvoltage category II

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category II					
	Creepage distance mm		Clearance mm	Withstand voltage ^b V		
	In equipment CTI ≥ 100	On printed wiring circuit board ^a CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,18	~~0,10~~ 0,025	~~0,10~~ 0,04	500	350	500
100	0,25	~~0,15~~ 0,10	~~0,15~~ 0,10	800	490	700
150	~~0,50~~ 0,31	~~0,50~~ 0,22	0,50	1 500	820	1 150
300	~~1,50~~ 0,70	~~1,50~~ 0,70	1,50	2 500	1 350	1 900
600	~~3,00~~ 1,68	~~3,00~~ 1,68	3,00	4 000	2 200	3 100
1 000	~~5,50~~ 3,20	~~5,50~~ 3,20	5,50	6 000	3 250	4 600

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b ~~For proving the clearance in air, see 10.6.3 and Table C.11.~~ For altitude correction to be applied, see Table C.12.

Table C.5 – Functional, basic or supplementary insulation, pollution degree 2, overvoltage category II

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category II								
	Creepage distance mm					Clearance mm	Withstand voltage ^c V		
	In equipment			On printed ~~wiring~~ circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	0,60	0,85	1,20	~~0,10~~ 0,04	~~0,10~~ 0,20	~~0,10~~ 0,20	500	350	500
100	~~0,70~~ 0,71	1,00	1,40	0,16	~~0,15~~ 0,20	~~0,15~~ 0,20	800	490	700
150	~~0,75~~ 0,79	~~1,05~~ 1,09	~~1,50~~ 1,57	~~0,50~~ 0,36	~~0,50~~ 0,22	0,50	1 500	820	1 150
300	1,50	2,10	3,00	~~1,50~~ 1,43	~~1,50~~ 0,70	1,50	2 500	1 350	1 900
600	3,00	4,30	6,00	~~3,00~~ 3,04	~~3,00~~ 1,68	3,00	4 000	2 200	3 100
1 000	~~5,50~~ 5,00	~~7,00~~ 7,10	10,00	~~5,50~~ 5,00	~~5,50~~ 3,20	5,50	6 000	3 250	4 600

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b See C.2.2 for minimum coating requirements.

^c ~~For proving the clearance in air, see 10.6.3 and Table C.11.~~ For altitude correction to be applied, see Table C.12.

Table C.6 – Functional, basic or supplementary insulation, pollution degree 1, overvoltage category III

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category III					
	Creepage distance mm		Clearance mm	Withstand voltage ^b V		
	In equipment CTI ≥ 100	On printed ^a wiring circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,18	0,15 0,025	0,15 0,10	800	490	700
100	0,50 0,25	0,50 0,10	0,50	1 500	820	1 150
150	1,50 0,31	1,50 0,22	1,50	2 500	1 350	1 900
300	3,00 0,70	3,00 0,70	3,00	4 000	2 200	3 100
600	5,50 1,68	5,50 1,68	5,50	6 000	3 250	4 600
1 000	8,00 3,20	8,00 3,20	8,00	8 000	4 350	6 150

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For proving the clearance in air, see 10.6.3 and Table C.11. For altitude correction to be applied, see Table C.12.

Table C.7 – Functional, basic or supplementary insulation, pollution degree 2, overvoltage category III

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category III								
	Creepage distance mm					Clearance mm	Withstand voltage ^c V		
	In equipment			On printed ~~wiring~~ circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	0,60	0,85	1,20	~~0,15~~ 0,04	~~0,10~~ 0,025	~~0,15~~ 0,20	800	~~490~~	700
100	~~0,70~~ 0,71	1,00	1,40	~~0,50~~ 0,16	~~0,50~~ 0,10	0,50	1 500	820	1 150
150	~~1,50~~ 0,79	~~1,50~~ 1,09	~~1,50~~ 1,57	~~1,50~~ 0,36	~~1,50~~ 0,22	1,50	2 500	1 350	1 900
300	~~3,00~~ 1,50	~~3,00~~ 2,10	3,00	~~3,00~~ 1,43	~~3,00~~ 0,70	3,00	4 000	2 200	3 100
600	~~5,50~~ 3,00	~~5,50~~ 4,30	6,00	~~5,50~~ 3,04	~~5,50~~ 1,68	5,50	6 000	3 250	4 600
1 000	~~8,00~~ 5,00	~~8,00~~ 7,10	10,00	~~8,00~~ 5,00	~~8,00~~ 3,20	8,00	8 000	4 350	6 150

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b See C.2.2 for minimum coating requirements.

^c ~~For proving the clearance in air, see 10.6.3 and Table C.11.~~ For altitude correction to be applied, see Table C.12.

Table C.8 – Double or reinforced insulation, pollution degree 1, overvoltage category II

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category II					
	Creepage distance mm		Clearance mm	Withstand voltage ^b V		
	In equipment CTI ≥ 100	On printed ^a wiring circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,36	0,15 0,05	0,15 0,10	800	490	700
100	0,50	0,50 0,20	0,50	1 500	820	1 150
150	1,50 0,62	1,50 0,44	1,50	2 500	1 350	1 900
300	3,00 1,40	3,00 1,40	3,00	4 000	2 200	3 100
600	5,50 3,36	5,50 3,36	5,50	6 000	3 250	4 600
1 000	8,00 6,40	8,00 6,40	8,00	8 000	4 350	6 150

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For proving the clearance in air, see 10.6.3 and Table C.11. For altitude correction to be applied, see Table C.12.

Table C.9 – Double or reinforced insulation, pollution degree 2, overvoltage category II

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category II								
	Creepage distance mm					Clearance mm	Withstand voltage ^c V		
	In equipment			On printed ~~wiring~~ circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	1,20	1,70	2,40	~~0,15~~ 0,08	~~0,15~~ 0,05	~~0,15~~ 0,20	800	490	700
100	~~1,40~~ 1,42	2,00	2,80	~~0,50~~ 0,32	~~0,50~~ 0,20	0,50	1 500	820	1 150
150	~~1,50~~ 1,57	~~2,10~~ 2,17	~~3,00~~ 3,14	~~1,50~~ 0,71	~~1,50~~ 0,45	1,50	2 500	1 350	1 900
300	3,00	~~4,20~~ 4,17	6,00	~~3,00~~ 2,86	~~3,00~~ 1,39	3,00	4 000	2 200	3 100
600	~~6,00~~ 6,08	~~8,60~~ 8,58	12,00	~~6,00~~ 6,08	~~5,50~~ 3,37	5,50	6 000	3 250	4 600
1 000	10,00	~~14,00~~ 14,20	20,00	10,00	~~8,00~~ 6,40	8,00	8 000	4 350	6 150

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b See C.2.2 for minimum coating requirements.

^c For proving the clearance in air, see 10.6.3 and Table C.11. For altitude correction to be applied, see Table C.12.

Table C.10 – Double or reinforced insulation, pollution degree 1, overvoltage category III

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category III					
	Creepage distance mm		Clearance mm	Withstand voltage V		
	In equipment CTI ≥ 100	On printed ^a wiring circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,50 0,36	0,50 0,05	0,50	1 500	820	1 150
100	1,50 0,50	1,50 0,20	1,50	2 500	1 350	1 900
150	3,00 0,62	3,00 0,44	3,00	4 000	2 200	3 100
300	5,50 1,40	5,50 1,40	5,50	6 000	3 250	4 600
600	8,00 3,36	8,00 3,36	8,00	8 000	4 350	6 150
1 000	14,00 6,40	14,00 6,40	14,00	12 000	6 500	9 200

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For proving the clearance in air, see 10.6.3 and Table C.11. For altitude correction to be applied, see Table C.12.

Table C.11 – Double or reinforced insulation, pollution degree 2, overvoltage category III

Nominal Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category III								
	Creepage distance mm					Clearance mm	Withstand voltage ^e V		
	In equipment			On printed ~~wiring~~ circuit board			Peak impulse ^c 1,2/50 μs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a, b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	1,20	1,70	2,40	~~0,50~~ 0,08	~~0,50~~ 0,05	0,50	1 500	820	1 150
100	~~1,50~~ 1,42	2,00	2,80	~~1,50~~ 0,32	~~1,50~~ 0,20	1,50	2 500	1 350	1 900
150	~~3,00~~ 1,57	~~3,00~~ 2,17	~~3,00~~ 3,14	~~3,00~~ 0,71	~~3,00~~ 0,45	3,00	4 000	2 200	3 100
300	~~5,50~~ 3,00	~~5,50~~ 4,17	6,00	~~5,50~~ 2,86	~~5,50~~ 1,39	5,50	6 000	3 250	4 600
600	~~8,00~~ 6,08	~~11,00~~ 8,58	12,00	~~8,00~~ 6,08	~~8,00~~ 3,37	8,00	8 000	4 350	6 150
1 000	~~14,00~~ 10,00	~~14,00~~ 14,20	20,00	~~14,00~~ 10,00	~~14,00~~ 6,40	14,00	12 000	6 500	9 200

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b See C.2.2 for minimum coating requirements.

^c ~~For proving the clearance in air, see 10.6.3 and Table C.11.~~ For altitude correction to be applied, see Table C.12.

Table C.12 – Test ~~voltage multiplication~~ site correction factor for proving the clearance in air

Test ~~site~~ altitude m	~~0 to 200~~	500	1 000	1 500	2 000	3 000	4 000	5 000
Test voltage multiplication factor	1,20	1,15	1,10	1,05	1	0,87	0,77	0,67

Table C.13 – Reduction of the pollution degree of internal environment through the use of additional protection within the equipment

Additional protection within the equipment	From pollution degree 2 of external environment to ^d	From pollution degree 3 of external environment to ^d
Constantly heated ^a	1	1
Encapsulated ^b	1	1
Coated ^c	1	2
Case hermetically sealed	1	1
Case protection meets IPX4 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013	2	2
^a This can be applied if the internal ambient temperature rise within the equipment is at least 5 °C. ^b Encapsulated: these are parts, including tracks and pads on the inner layers of printed circuit boards, which have been totally covered in an encapsulation material such as epoxy resin, and this is considered as solid insulation. This encapsulation provides a barrier between any condensation on the surface of the encapsulant and the surfaces of components and conductors which are encapsulated. ^c Coated: applies to printed circuit conductors covered by solder resist or to conductors or components which have been covered by a conformal coating. ^d If Table C.13 is used to determine reduced creepage distance, it should be ensured that this is not less than the minimum allowed clearance.		

Annex D (informative)

Components

D.1 General

This Annex D provides guidance for components which could cause safety risks if not adequately designed and constructed.

Consideration should be given to the fact that, on a long-term basis, the electrical and mechanical properties of some insulating materials can be adversely affected, for example, by softeners evaporating at temperatures below the normal softening temperature of the material.

The relative thermal index (RTI), where specified for the material, provides the maximum continuous operating temperature at which its electrical and mechanical properties may reduce by up to 50 % over a period of seven years.

D.2 Introductory remark

For safety reasons, components ~~shall~~ should comply either with the requirements of this document or with the safety aspects of the relevant IEC component standards.

NOTE 1 An IEC component standard is considered relevant only if the component in question clearly falls within its scope.

A component which is to be connected to a PEB, PELV or SELV circuit and also to an ELV circuit or to a part at hazardous voltage ~~shall~~ should comply with ~~the requirements below~~ Clause D.3 to Clause D.9 for a PEB, PELV or SELV circuit.

PEB, PELV and SELV circuits ~~shall~~ should exhibit voltages safe to touch both under normal operating conditions and after a single fault, such as breakdown of a layer of basic insulation or failure of a single component.

NOTE 2 An example of such a component is a relay with different supplies connected to different elements (coils and contacts).

The manufacturer ~~shall~~ should ensure that all safety-related components meet the safety requirements of this document.

For batteries, see 7.6.2.2.

Specific safety-related components are as follows.

D.3 Transformers

Transformers ~~shall~~ should be of a type suitable for their intended application and ~~shall~~ should comply with the relevant requirements of this document, for example, clearance and creepage distance according to Annex C, solid insulation if appropriate according to 4.8 and protection against fire according to Clause 6.

D.4 Equipment primary circuit capacitors

Capacitors used in primary circuits should be of the self-healing type to avoid short circuits when these are subjected to transient voltages which ~~may~~ can be present on the AC or DC supply.

A capacitor connected between a supply conductor and the protective conductor circuit, for EMC decoupling to earth ~~shall~~ should be Y rated complying with IEC 60384-14. For basic insulation these ~~shall~~ should be rated to withstand 2 000 V AC RMS for 1 min or 2 200 V AC RMS for 1 s. For any double insulation requirement, the rated withstand ~~shall~~ should be 3 250 V AC RMS for 1 min or 3 575 V AC RMS for 1 s.

A capacitor connected between two supply conductors ~~shall~~ should be one of the following:

- a) an X1 capacitor complying with IEC 60384-14;
- b) an X2 capacitor which passes the impulse test of IEC 60384-14, as applied to X1 capacitors, with the test voltage reduced to 2,5 kV;
- c) an X2 capacitor which passes the endurance test of IEC 60384-14, with the 220 Ω resistor short-circuited (Annex B of IEC 60384-14:2013).

D.5 Coil devices – transformers, instrument transformers and transducers, reactors, and operating coils of relays and contactors with multiple windings and/or screen

D.5.1 Coil windings

To maintain the minimum required separation distances between windings, measures which prevent the following should be implemented:

- undesirable shifting of the windings or of their turns, especially at the edge of the winding layers;
- undesirable shifting of turns or of the inner wiring, in the case of breakage near connections or of unfastening or detachment of connections.

Measures taken against undesirable shifting of windings or wires can include the following:

- a) windings with or without coil form, on different limbs of the core;
- b) windings in different chambers of the coil form; in the event that the partition walls of the chambers are merely inserted into place, sufficient coverage of the intervening joint should be ensured;
- c) intermediate layers made of stiff insulation material which extend sufficiently beyond the windings when used with flangeless windings, or which completely fill the clearance width between flanges when used with coil forms with flanges; in the latter case, the intervening joint space up to the flange should also be sufficiently covered;
- d) filling out of incompletely wound winding layers by means of insulation material;
- e) intermediate layer consisting of several thicknesses of feathered sheeting of such a width that the feathering lies flush against the flange of the coil form and thereby prevents individual edge windings from slipping through; for feathered edge tape to act as an insulation barrier between windings, insulation barrier impregnation or casting of the windings is required as per item h) below;
- f) layer-by-layer winding with insulating intermediate layers, for example, with feathered sheeting;
- g) securing of the edge windings by means of adhesive tape or other suitable means of fastening;
- h) impregnation or casting of the windings with material which hardens and completely fills out the intermediate spaces and which securely holds the edge windings; vacuum impregnation

or casting is recommended, in order to extensively exclude the formation of gas bubbles (the presence of which could promote partial discharge).

Such impregnation or casting fulfils the purpose required, but only if sufficient care is taken to ensure that undesirable shifting of a winding does not occur before hardening. Production faults, mechanical action, or thermal effects can cause such undesired shifting.

Care should be taken that any clearances or creepage distances (which may develop over gaps and separating joints of the coil forms, or over intermediate layers, and which ~~may not be able to~~ cannot be reliably eliminated by impregnation or casting) comply at least with the values stipulated in 4.9 and Annex C.

D.5.2 Insulating foil

If insulating foil is to be used for insulation, then this foil should consist of at least two layers for basic insulation purposes. For purposes of reinforced insulation, it should consist of at least three layers. Varnish or enamel insulation of the wires should not be considered as insulation with respect to another circuit or to an accessible conductive part.

D.5.3 Interposing protective screen

The protective screen between concentrically configured windings should cover the adjacent windings over the entire width and the entire extent and/or there ~~shall~~ should be adequate clearance and creepage distance between the windings. The protective screen may also consist of an appropriately designed shielding winding.

D.5.4 Safety isolation transformers

Safety ~~insulation~~ isolation transformers in accordance with IEC 61558 may be employed (with observance of the restrictions of the scope of application of IEC 61558, for example, rated frequency < 500 Hz) under the condition that the double or reinforced insulation between the protectively separated circuits does not produce partial discharges which ~~may~~ can reduce the insulation withstand.

Safety isolation transformers above 500 Hz are under consideration.

NOTE When conducting the voltage test of safety isolating transformers in accordance with IEC 61558, there is ~~the danger~~ a hazardous situation that the test will damage the insulation between the input and output side as a result of the partial discharge which occurs. The stipulated partial-discharge test mentioned above serves to identify unsuitable transformers.

D.6 Electromechanical components

Electromechanical components which form an interface between different circuits (switches, all-or-nothing relays, contactors, circuit-breakers) ~~shall~~ should comply with the points below.

- a) It is especially important in cases of encapsulated electromechanical components (for example, all-or-nothing relays, see IEC 61810-1) to ensure that the unfastening or detachment of a movable part (for example, contact pieces, contact springs and the like) will not result in damage of the insulation provided for purposes of protective separation.
- b) In the case of strong electrical arcs due to external connection, the creepage distances which serve for protective separation should be configured in such a manner that they maintain their long-term insulation function. Protection can be afforded, for example, by ensuring sufficient physical separation or by encapsulation.

D.7 Semiconductor components and semiconductor configurations

Semiconductor junctions for use as protective separation of circuits are not permitted.

Semiconductor configurations, also including hybrids, for example, semiconductor contactors, electronic transformers and convertors, optical couplers, isolation amplifiers, and compact power supplies are permitted for basic insulation and reinforced insulation if they are designed and implemented to withstand the appropriate voltage tests without tracking. The insulation resistance test can be used to determine if there has been any detrimental tracking.

The energy or information transfer interfaces for protective separation should then satisfy the requirement for coil devices (according to Clause D.5) or for optical coupler elements.

Laser components ~~shall~~ should be in accordance with IEC 60825-1.

D.8 Connectors and terminal blocks

Insulation may be provided within connectors for connecting leads, or for electrical connection for sub-assemblies by omitting or not connecting contact tips or points (for example, creating space). A bent or broken-off contact tip ~~or~~ point should not impair the insulation to the extent that it no longer fulfils the requirements for basic insulation.

The requirements ~~5.2.8.5 and 7.1.9 of IEC 62103:2003~~ 4.11.5 of IEC 62477-1:2022 apply for the non-interchangeability and for protection against polarity reversal of connectors.

In the case of terminal blocks for the connection of sub-assemblies and devices, additional measures are required (in addition to those for sufficient clearances and creepage distances) to effectively prevent the unintentional false connection of such equipment. These measures should be implemented by at least one of the following:

- a) a separation interval of at least the width of one terminal clamp;
- b) one terminal clamp which is not connected;
- c) one terminal clamp connected to the protective conductor;
- d) one intermediate insulating piece which extends above the terminals on the connection sides;
- e) one protective screen which extends above the terminals on the connection sides;
- f) employment of terminals of different sizes for these circuits;
- g) employment of highly obvious designation, for example, by apparent colour coding.

See also 7.2.

When breaking the connection of connectors and terminal blocks and when there is a ~~danger~~ hazardous situation through mechanical action of breaking a lead or unfastening or detaching a lead, the insulation could be damaged to the extent that the requirements for basic insulation are no longer satisfied. Effective measures should be taken to prevent such damage.

D.9 Voltage dependent resistors (VDRs)

A VDR should consider all of the following:

- a) Maximum continuous voltage:
 - at least 1,25 times the rated voltage of the equipment; or
 - at least 1,25 times the upper voltage of the rated voltage range.

NOTE The maximum continuous voltages are not limited to values specified in IEC 61051-2.

- b) Combination pulse (Table I group 1 of IEC 61051-2:2021).

For the test, a combination pulse is selected from 2.3.6 in IEC 61051-2:2021. The test consists of 10 positive pulses or 10 negative pulses, each having a shape of 1,2/50 μ s for voltage and 8/20 μ s for current.

Rated voltage under 300 V is considered to be 300 V. For working voltages of 300 V up to overvoltage category IV and 600 V up to overvoltage category III, devices complying with UL 1449 are considered to meet these requirements.

For overvoltage category IV a combination pulse 6 kV/3 kA is used except for equipment intended for connection to a system supply of 600 V, for which a combination pulse of 8 kV/4 kA is used. As an alternative to the 6 kV/3 kA test, the combination pulse test of IEC 61051-2:2021 (2.3.6, Table I group 1 and Annex A), including consideration of the rated voltage and overvoltage category, is acceptable.

In addition to the performance requirements of Table I group 1 of IEC 61051-2:2021, the VDR voltage at the manufacturer's specified current after the test should not have changed by more than 10 % when compared to the value before the test.

The body of the VDR should comply with the needle flame according to IEC 60695-11-5, with the following test severities:

- duration of application of the test flame: 10 s;
- after flame time: 5 s.

If the body of the VDR complies with V-1 class material, the needle flame test does not need to be performed.

D.10 Intentional radio transmitters

Intentional radio transmitters to comply with health and safety legislation need to ensure that the power and frequency remain within the limits for the standards with which they are compliant. The intentional transmitters are outside the scope of this document and the communication specific standards will take precedence such as IEC 62479 and IEC 62368-1 (dedicated safety).

Annex E (normative)

External wiring terminations

E.1 General

This Annex E provides ~~guidance~~ provisions for external wiring terminations of equipment in the scope of this document.

E.2 Permanently connected equipment

Permanently connected equipment shall be provided with either:

- a) a set of terminals; or
- b) a non-detachable power supply cable.

Equipment designed for permanent connection and equipment with ordinary non-detachable power supply cables shall be provided with terminals in which connection is made by means of screws (screws or nuts with lock washers are not regarded as liable to become loose, nor are wires which are mechanically secured by more than soldering alone), nuts or equally effective devices (not removable without the use of a tool), to provide mechanical security.

This applies to **current transformer (CT)** and **voltage transformer (VT)** connections in addition to those for the AC or DC supply and protective conductors. It also applies to input and output connections for which the voltage is in excess of ELV voltage levels.

Screws and nuts which clamp external power supply conductors shall have a thread conforming to international standards (for example, unified threads).

The screws and nuts shall not be used to secure components. They are, however, permitted to clamp internal conductors, provided that these are arranged in such a way that it is unlikely that they will be displaced by insertion or removal of the supply or protective conductors.

For the purpose of applying the requirements for power supply cables:

- it is assumed that two independent fixings will not become loose at the same time;
- crimped conductors shall be mechanically retained, for example, by an insulation clamp or additional fixing close to the terminal.

~~Compliance~~ **Conformity** with Clause E.2 is checked by inspection.

E.3 Conductors

Terminals shall allow the connection of conductors having ~~nominal~~ cross-sectional areas as shown in Table E.1.

Where heavier gauge conductors are used, the terminals shall be sized accordingly.

~~Compliance~~ **Conformity** with Clause E.3 is checked by inspection and by fitting cables of the smallest and largest cross-sectional areas of the appropriate range shown in Table E.1.

Table E.1 – Range of conductor sizes to be accepted by terminals

Cable termination application	Recommended cable size mm ²
CT circuits	2,5 to 6,0
Alarm and signalling, for example, SCADA	≥ 0,5 ~~min~~
~~Communication circuits~~ Wired network port, for example, RS232	As recommended by the manufacturer
Other circuits, for example, VT, auxiliary, etc.	1,0 to 2,5

E.4 Terminals

Terminals shall have minimum sizes as shown in Table E.2. Stud terminals shall be provided with washers.

Table E.2 – Sizes of terminal studs or screws directly securing supply conductors

Rated current of equipment	Minimum ~~nominal~~ thread diameter mm	
	Pillar or stud size	Screw size ^{a,b}
Up to and including 10 A	3,0	3,5
Over 10 A up to and including 16 A	3,5	4,0
^a Screw size refers to a terminal that clamps the conductor under the head of a screw, with or without a washer. This does not exclude the indirect securing of conductors by other means, for example, a "moving cage clamp", using smaller screw sizes.		
^b If the screw size does not meet these requirements, the manufacturer shall demonstrate conformity by type testing. The resultant temperature at maximum current and at maximum ambient temperature, shall not exceed the ratings of the materials used. The terminations shall remain mechanically secure.		

Terminals shall be so designed that they clamp the conductor between metal surfaces with sufficient contact pressure and without damage to the conductor.

Terminals shall be so designed or located that the conductor cannot slip out when the clamping screws or nuts are tightened.

Terminals shall be so fixed that when the means of clamping the conductor is tightened or loosened:

- a) the terminal itself does not work loose;
- b) internal wiring is not subjected to stress;
- c) creepage distances and clearances are not reduced below the values specified in Annex C.

~~Compliance~~ **Conformity** with the requirements of Clause E.4 is checked by inspection and measurement.

For ordinary non-detachable power supply cables, each terminal shall be located in proximity to its corresponding terminal or terminals of different potential.

~~Compliance~~ **Conformity** of non-detachable power supply cables is checked by inspection.

Annex F (informative)

Examples of battery protection

This Annex F gives typical examples of battery protection to reduce overheating or explosion risk under a single fault condition. See Figure F.1 and Figure F.2.

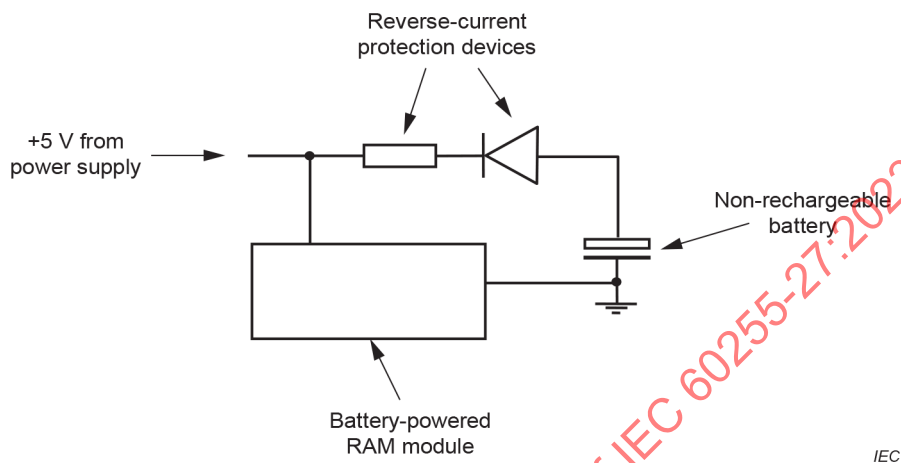
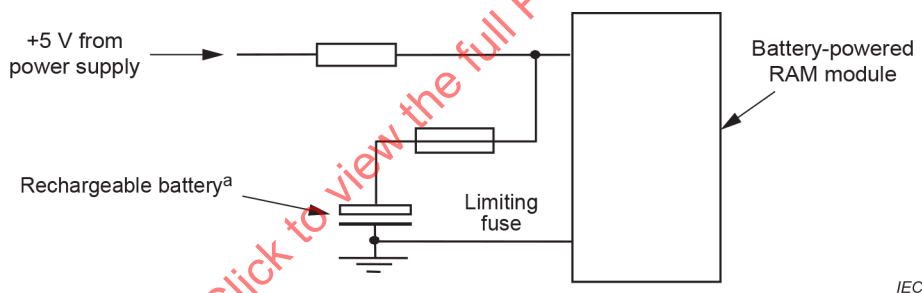


Figure F.1 – Non-rechargeable battery protection



^a Charge and discharge currents shall be limited to safe values.

Figure F.2 – Rechargeable battery protection

Annex G (informative)

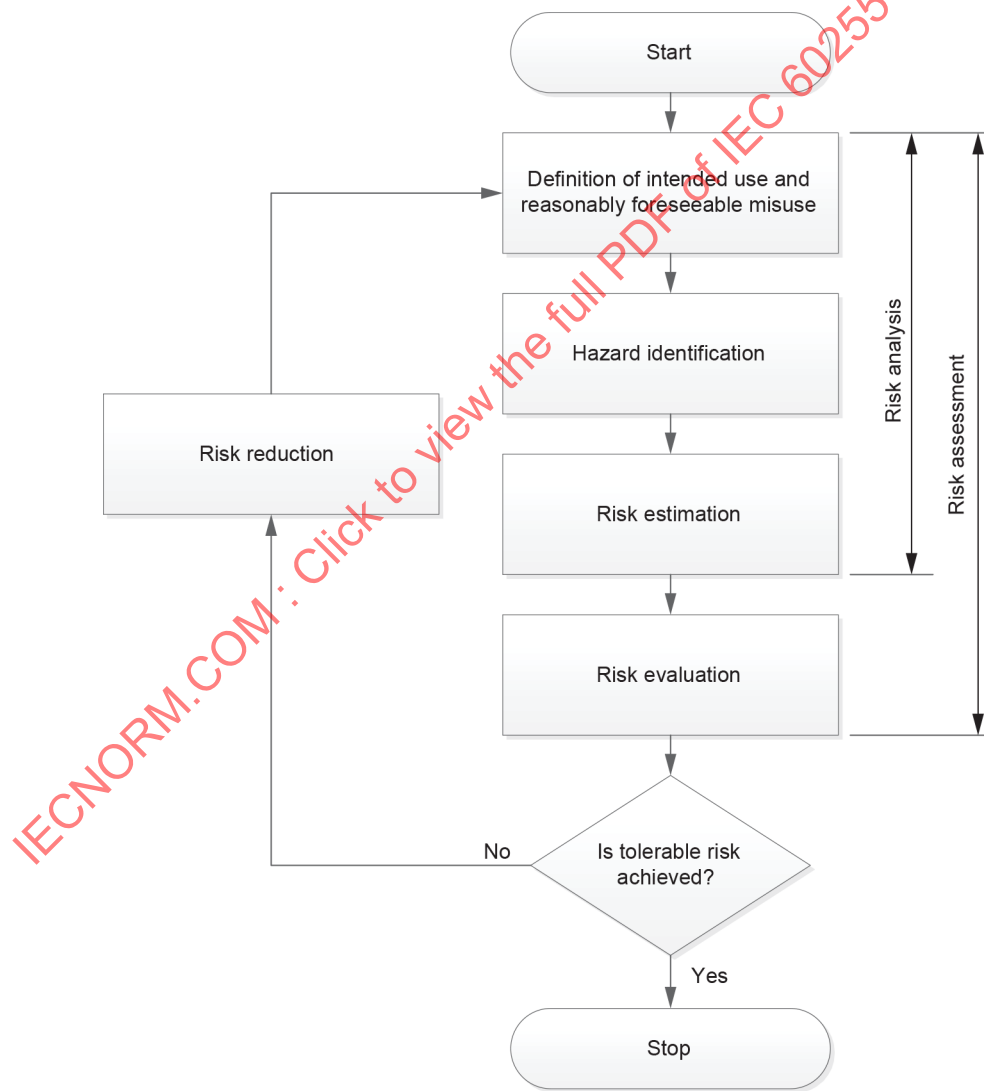
Risk assessment 31

G.1 General

A risk assessment process based on ISO/IEC Guide 51 and IEC 61010-1 is given below. In IEC 61508 other risk assessment procedures are contained which implement similar steps and can also be used.

G.2 Risk assessment procedure

Tolerable risk is achieved by the iterative process of risk assessment (risk analysis and risk evaluation) and risk reduction (see Figure G.1).



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Figure G.1 – Iterative process of risk assessment and risk reduction

G.3 Achieving tolerable risk

The following procedure (see Figure G.1) should be used to reduce risks to a tolerable level:

- identify the likely user group(s) for the product, process, or service;
- identify the intended use and assess the reasonably foreseeable misuse of the product, process or service;
- identify each hazard (including any hazardous situation and harmful event) arising in all stages and conditions for the use of the product, process or service, including installation, maintenance, repair, and disposal;
- estimate and evaluate the risk (see Figure G.1) to each identified user and/or contact group arising from each hazard identified;
- judge if the risk is tolerable (e.g. by comparison with similar products, processes or services);
- if the risk is not tolerable, reduce the risk until it becomes tolerable.

When reducing risks the order of priority should be as follows:

- eliminate or reduce risks as far as possible (inherently safe design and construction);
- take the necessary protection measures in relation to risks that cannot be eliminated (protection devices);
- inform users of the residual risks due to any shortcomings of the protection measures adopted, indicate whether any particular training is required, and specify any need to provide personal protective equipment (information for safety).

This procedure assumes that the user has a role to play in the risk reduction procedure by complying with the information provided by the manufacturer (see Figure G.2).

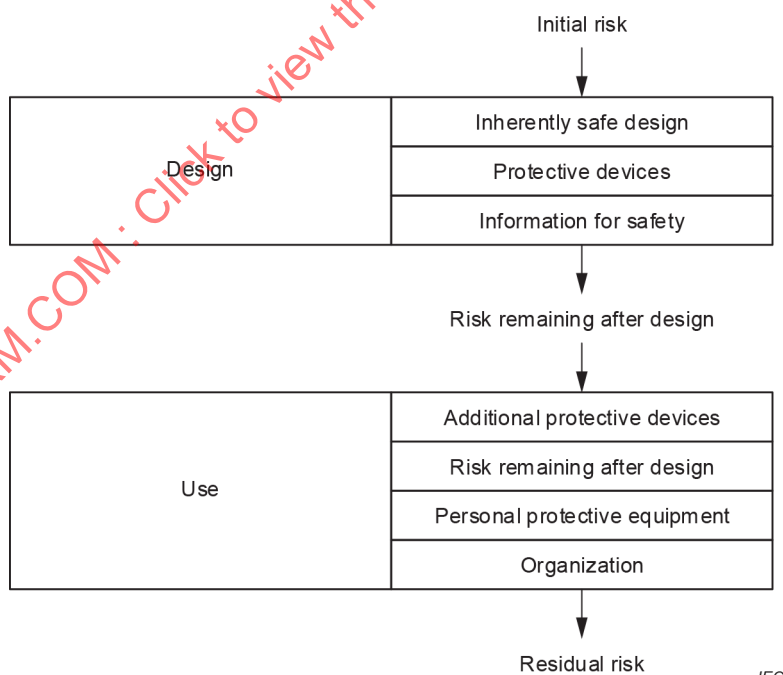


Figure G.2 – Risk reduction

The steps taken in the design procedure are shown in order of priority. The steps to be taken by the user are not in order of priority because this would depend on the application. It is emphasized that the additional protection devices, personal protective equipment and provision of information to users should not be used as substitutes for design improvements.

G.4 An application of risk assessment procedures

For hazards in the scope of this document, examples of severity of harm are given in Table G.1. Probability of harm is given in Table G.2. The risk category, which is selected based on severity and probability, is given in Table G.3.

Table G.1 – Severity of harm

Severity group	People	Equipment or facility	Environment
Catastrophic	One or more fatalities	System or facility loss	Chemical release with acute or public health impact
Severe	Disabling injury or illness	Major subsystem loss or facility damage	Chemical release with temporary environmental or public health impact
Moderate	Medical treatment or restricted work activity	Minor subsystem loss or facility damage	Chemical release triggering external reporting requirements
Minor	First aid only	Non-serious equipment or facility damage	Chemical release requiring only routine cleanup without reporting

Table G.2 – Probability of harm

Likelihood	Expected rate of occurrence
Frequent	More than five times a year
Likely	More than once per year, but not more than five times a year
Possible	More than once in five years, but not more than once a year
Rare	More than once in ten years, but not more than once in five years
Unlikely	No more than once in ten years

Table G.3 – Risk category

Risk assessment / risk category						
Severity of harm		Probability of harm				
		Frequent	Likely	Possible	Rare	Unlikely
Severity	Catastrophic	3	3	3	2	2
	Severe	3	3	2	2	1
	Moderate	3	2	1	1	1
	Minor	2	1	1	1	1
Key	Category	Description				
1	Broadly acceptable	This fulfils the requirement for tolerable risk.				
2	As low as reasonably practicable	This does not automatically fulfil the requirement for tolerable risk. If possible, these risks should be reduced further to Category 1. If not possible, then the instructions should contain a description of the risk so that the responsible body can take appropriate steps to protect the safety of operators.				
3	Intolerable	This contains risks that are not tolerable risks.				

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~~ISO 9772:2001, Cellular plastics — Determination of horizontal burning characteristics of small specimens subjected to a small flame~~

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List of comments

- 1 It is made clear that this standard is looking for safety aspects and is not concerned with the functional operation of the product.
- 2 LPIT, LPCT and LPVT are added as more products are having these types of ports.
- 3 The communications port reference is removed and replaced with wired network port which is now standardised across IEC 60255-1 and IEC 60255-26.
- 4 The substation environment is a restricted access area and this is reiterated here as this defines the level of safety required.
- 5 The IP rating and safety against electric shock are interlinked. Table 1 is added to clarify the safety requirements for protection against electric shock when applied to substation environments.
- 6 This section is removed as the holes in the top of the case make the test unnecessary.
- 7 The voltage levels are reduced to align with other safety standards.
- 8 Interpolation of voltages was consigned to a note, this is moved into the main body of the document as it is fundamental.
- 9 It is clarified that double or reinforced insulation does not require single fault testing rather than having it buried further down within the section.
- 10 The voltage levels are reduced to align with other safety standards.
- 11 The requirements have not changed, the previous wording is simplified.
- 12 The voltage levels are reduced to align with other safety standards.
- 13 High currents will produce a magnetic field that can cause wiring to be displaced. Transformers are susceptible to this and wiring needs to be restrained.
- 14 No change in requirement but the wording is simplified to aid understanding.
- 15 This clarifies the location of warning symbol and the associated hazard symbol.
- 16 Performing the tests in Section 9 will not provide conformity with IEC 60255-27. To achieve this it requires a full clause by clause assessment against the standard.
- 17 Dielectric and insulation testing are added to temperature and humidity tests to ensure that insulation has not degraded.
- 18 Dielectric and impulse testing are added to mechanical tests to ensure that insulation has not been damaged.
- 19 It is recognised that hardware is shared across platforms. Testing a single product can be used to cover the range but this rationale shall be documented.
- 20 Sample testing are removed as safety testing of protective relays are categorised as type testing or routine tests.
- 21 This is a new requirement for the mechanical tests.
- 22 The previous standard referred to the dust and water ingress. This is modified as this standard is product safety specific, therefore all forms of protection that the case provides are relevant.
- 23 This section is simplified and reference is made to the creepage and clearance table in Annex C.

- 24 The reduction of impulse voltage if the test is carried out more than once is removed as these are type tests on new products.
- 25 This section is simplified and reference is made to the creepage and clearance table in Annex C.
- 26 The move to lower power inputs has reduced the insulation withstand and this has been reflected in other safety standards. IEC 60255-27 lowers this to match other standards.
- 27 The 100-In test here is for safety testing only, the relay does not have to operate. Of importance here is the integrity of the insulation.
- 28 This is a new test. The aim is to apply a high fault current and verify that the mechanical integrity of the transformer is not compromised.
- 29 In the previous standard it was assumed that the mechanical robustness of the product would be designed in with no formal test. This was not ideal, and a standardised test method is added.
- 30 Tables C.2 to C.11 are updated since the previous standard had some round and interpretation and did not follow the base standard. This lead to confusion and these tables are updated to align now with the base standard.
- 31 Guidance is added for creation of risk assessments to cover the application of common hardware across products.

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Measuring relays and protection equipment –
Part 27: Product safety requirements**

**Relais de mesure et dispositifs de protection –
Partie 27: Exigences de sécurité des produits**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MEASURING RELAYS AND PROTECTION EQUIPMENT –**Part 27: Product safety requirements**

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IEC 60255-27 has been prepared by IEC technical committee 95: Measuring relays and protection equipment. It is an International Standard.

This third edition cancels and replaces the second edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) conflicting statements removed;
- b) scope clarified and statement added that all clauses of the standard are required not just type tests;
- c) terminology, definitions and documentation requirements aligned with IEC 60255-1;
- d) alignment with IEC 61010-1, e.g. HLV definitions;
- e) ingress protection clarified;
- f) dielectric and impulse tests added to mechanical and environmental test requirements;

- g) insulation resistance requirements updated for alignment with other product safety standards;
- h) sample testing removed;
- i) short time limiting thermal overload added;
- j) resistance to mechanical stress added;
- k) low-power voltage and current transformer ports added;
- l) Annex C tables updated to align with base standards;
- m) Annex D voltage dependent resistors and radio transmitters added;
- n) Annex G for risk assessment added.

The text of this International Standard is based on the following documents:

Draft	Report on voting
95/516/FDIS	95/526/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60255 series, published under the general title *Measuring relays and protection equipment*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This document specifies the safety requirements that are generally applicable to all equipment within its scope. These requirements may be supplemented by general product safety standards and IEC 60664-1.

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MEASURING RELAYS AND PROTECTION EQUIPMENT –

Part 27: Product safety requirements

1 Scope

This part of IEC 60255 specifies the product safety requirements for measuring relays and protection equipment having a rated AC voltage up to 1 000 V, or a rated DC voltage up to 1 500 V. Above these limits, IEC 60664-1 is applicable for the determination of clearance, creepage distance and withstand test voltage.

This document specifies essential safety requirements to minimize the risk of fire and hazards caused by electric shock or injury to the user and property. This document specifies only product safety requirements; functional performance of the equipment is not covered.

This document covers all the ways in which the equipment can be mounted and used in cabinets, racks and panels. This document also applies to auxiliary devices such as shunts, series resistors, transformers, auxiliary control panels, display devices, etc., that are used in conjunction with measuring relays and protection equipment and are tested together.

It is possible that ancillary equipment such as network switches used in conjunction with measuring relays and protection equipment needs to comply with additional safety requirements.

This document does not specify the implementation of individual equipment, circuits and components.

This document applies to equipment designed to be safe at least under the following environmental conditions:

- indoor use;
- altitude up to 2 000 m, in accordance with IEC 60255-1;
- rated ambient temperature range, in accordance with IEC 60255-1;
- maximum external relative humidity, in accordance with IEC 60255-1;
- operating range of auxiliary energizing voltage in accordance with IEC 60255-1;
- applicable overvoltage category;
- applicable pollution degree of the intended environment (pollution degree 2 in most cases).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60127-1, *Miniature fuses – Part 1: Definitions for miniature fuses and general requirements for miniature fuse-links*

IEC 60255-1, *Measuring relays and protection equipment – Part 1: Common requirements*

IEC 60255-26, *Measuring relays and protection equipment – Part 26: Electromagnetic compatibility requirements*

IEC 60352-1, *Solderless connections – Part 1: Wrapped connections – General requirements, test methods and practical guidance*

IEC 60352-2, *Solderless connections – Part 2: Crimped connections – General requirements, test methods and practical guidance*

IEC 60417, *Graphical symbols for use on equipment*. Available at: <http://www.graphical-symbols.info/equipment>

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

IEC 60664-3, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

IEC TS 60695-2-20, *Fire hazard testing – Part 2-20: Glowing/hot-wire based test methods – Hot-wire coil test method – Apparatus, test method and guidance*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

IEC 61010-1:2010/AMD1:2016

IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61051-2:2021, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61180, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

IEC 61869-6, *Instrument transformers – Part 6: Additional general requirements for low-power instrument transformers*

IEC 61869-10, *Instrument transformers – Part 10: Additional requirements for low-power passive current transformers*

IEC 61869-11, *Instrument transformers – Part 11: Additional requirements for low-power passive voltage transformers*

IEC 62151, *Safety of equipment electrically connected to a telecommunication network*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

accessible conductive part

conductive part of electrical equipment touchable under normal use

3.2

accessible part

part which can be touched under normal use with a standard rigid or jointed test finger as specified in 6.2 of IEC 61010-1:2010 and IEC 61010-1:2010/AMD1:2016

Note 1 to entry: Circuits intended to be connected to an external accessible circuit are considered as accessible conductive parts, for example wired network ports.

3.3

adjacent circuit

independent circuit

electric circuit which is separated from the considered circuit by applicable insulation

3.4

ambient temperature

ambient air temperature

temperature, determined under prescribed conditions, of the air surrounding the complete equipment

Note 1 to entry: For equipment installed inside an enclosure, it is the temperature of the air outside the enclosure.

Note 2 to entry: The ambient temperature is measured at half the distance from any neighbouring equipment, but not more than 300 mm distance from the equipment case, at middle height of the equipment, protected from direct heat radiation from the equipment.

[SOURCE: IEC 60050-441:1984, 441-11-13, modified – The preferred term "ambient temperature" has been added. In the definition and Note 1 to entry, "switching device or fuse" has been replaced by "equipment". Note 2 to entry has been added.]

3.5

barrier

electrically protective barrier

part providing protection against direct contact from any usual direction of access that is firmly secured in place in such a way that it can only be removed by the use of a tool

[SOURCE: IEC 60050-826:2004, 826-12-23, modified – The preferred term "barrier" has been added. At the end of the definition, "that is firmly secured in place in such a way that it can only be removed by the use of a tool" has been added.]

3.6

basic insulation

insulation of hazardous-live-parts to provide basic protection

[SOURCE: IEC 60050-826:2004, 826-12-14, modified – In the definition, "which provides" has been replaced by "to provide" and the Note has been removed.]

3.7**basic protection**

protection against electric shock under normal conditions

[SOURCE: IEC 60050-195:2021, 195-06-01]

3.8**bounding surface**

outer surface of the equipment case

3.9**cabinet**

free-standing and self-supporting enclosure for housing electrical and/or electronic equipment

Note 1 to entry: A cabinet is usually fitted with doors and/or side panels, which may or may not be removable.

[SOURCE: IEC 60050-581:2008, 581-25-02]

3.10**clearance**

shortest distance, measured in air, between two conductive parts, or between a conductive part and the outer bounding surface of the equipment, whether conductive or not

3.11**comparative tracking index****CTI**

numerical value of the maximum voltage in volts which a material can withstand without tracking and without a persistent flame occurring under specified test conditions

[SOURCE: IEC 60050-212:2010, 212-11-59]

3.12**creepage distance**

shortest distance along the surface of a solid insulating material between two conductive parts, or between a conductive part and the bounding surface (accessible part) of the equipment, measured along the surface of insulation

[SOURCE: IEC 60050-151:2001, 151-15-50, modified – The phrase ", or between a conductive part and the bounding surface (accessible part) of the equipment, measured along the surface of insulation" has been added.]

3.13**direct contact**

electric contact of persons with live parts

[SOURCE: IEC 60050-826:2004, 826-12-03, modified – In the definition, the words "or animals" have been omitted.]

3.14**double insulation**

insulation comprising both basic insulation and supplementary insulation

Note 1 to entry: Basic and supplementary insulation are separate, each designed for basic protection against electric shock.

[SOURCE: IEC 60050-195:2021, 195-06-08, modified – The note to entry has been added.]

3.15

enclosure

housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: Enclosures can provide protection against the spread of fire (see Clause 7).

[SOURCE: IEC 60050-151:2001, 151-13-08, modified – Note 1 to entry has been added.]

3.16

extra low voltage

ELV

voltage not exceeding the maximum value of the prospective touch voltage that is acceptable to be maintained indefinitely under specified conditions of external influences

Note 1 to entry: For the purposes of this document, the ELV values are specified in 4.3.3.2.

SEE: Table A.1

[SOURCE: IEC 60050-195:2021, 195-05-24, modified – The note to entry has been added.]

3.17

fire enclosure

enclosure intended as a safeguard against the spread of fire from within the enclosure to outside the enclosure

[SOURCE: IEC 60050-903:2014, 903-04-10, modified – In the definition, the word "protection" has been replaced by "as safeguard", and Note 1 to entry has been deleted.]

3.18

functional earthed circuit

functional grounded circuit, US

circuit that can include PCB tracks, wiring, components and equipotential bonds that is connected to earth for purposes other than electrical safety

Note 1 to entry: Purposes other than electrical safety include screening and reference point for measurements.

3.19

functional insulation

insulation between conductive parts, necessary for the proper functioning of the equipment

[SOURCE: IEC 60050-195:2021, 195-02-41]

3.20

hazardous energy level

available power level of 240 VA or more, having a duration of 60 s or more, or a stored energy level of 20 J or more (for example, from one or more capacitors), at a potential of 2 V or more

3.21

hazardous-live-part

live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-826:2004, 826-12-13]

3.22

hazardous live voltage

HLV

normal use voltage which exceeds ELV levels

Note 1 to entry: For the purposes of this document the ELV values are specified in 4.3.3.2.

3.23**high-integrity part****high-integrity component**

part or component whose specification or qualification is well in excess of the application such that the risk of failure is minimal

3.24**live part**

conductive part intended to be energized under normal operating conditions, including the neutral conductor

[SOURCE: IEC 60050-195:2021, 195-02-19, modified – The last part of the definition " and mid-point conductor, but excluding the PEN conductor, PEM conductor and PEL conductor" has been omitted.]

3.25**low-power instrument transformer****LPIT**

arrangement, consisting of one or more current or voltage transformer(s) which may be connected to transmitting systems and secondary converters, all intended to transmit a low-power analogue or digital output signal to measuring instruments, meters and protective or control devices or similar apparatus

EXAMPLE An arrangement consisting of three current sensors, three voltage sensors connected to one merging unit delivering one digital output is considered an LPIT.

Note 1 to entry: LPITs are commonly called non-conventional instrument transformers (NCIT).

Note 2 to entry: The output power produced by these devices is typically lower than or equal to 1 VA.

[SOURCE: IEC 61869-6:2016, 3.1.601]

3.26**low-power current transformer****LPCT**

low-power instrument transformer for current measurement

[SOURCE: IEC 61869-6:2016, 3.1.602]

3.27**low-power voltage transformer****LPVT**

low-power instrument transformer for voltage measurement

[SOURCE: IEC 61869-6:2016, 3.1.603]

3.28**maintenance use**

state of the equipment when being serviced by trained personnel with any tool removable covers and protective measures removed

3.29**non-primary circuit**

circuit electrically isolated from the AC or DC supply and from external voltage transformers and current transformers

3.30

normal use

state of the equipment when installed and operated for its intended purpose, with any tool removable covers and protective measures in place

3.31

overheating

operating at a level such that the thermal limit is exceeded

3.32

overvoltage category

numeral defining a transient overvoltage condition

Note 1 to entry: Overvoltage categories I, II, III and IV are used, see IEC 60664-1.

[SOURCE: IEC 60050-426:2020, 426-04-48]

3.33

protective class I equipment

equipment with basic insulation and protective bonding for protection against electric shock, such that conductive parts on the outside of the equipment case cannot become live (in the event of a failure of the basic insulation)

3.34

protective class II equipment

equipment with

- basic insulation as provision for basic protection against electric shock, and supplementary insulation as provision for fault protection; or
- double- or reinforced-insulation basic and fault protection

Note 1 to entry: There should be no provision for a protective conductor or reliance upon installation conditions for safety purposes. It is, however, possible to connect an earth conductor to protective Class II equipment for functional (for example, EMC) purposes.

3.35

protective class III equipment

equipment, or parts of equipment, in which protection against electric shock relies upon supply from SELV or PELV circuits and in which hazardous voltages are not generated

3.36

pollution

addition of foreign matter, solid, liquid or gaseous that can produce a reduction of dielectric strength or surface resistivity of the insulation

[SOURCE: IEC 60050-442:1998, 442-01-28, modified – In the definition, the word "permanent" has been deleted, and the note has been omitted.]

3.37

pollution degree

number characterizing the expected pollution of the ambient conditions which immediately surround the clearance and creepage distance under consideration as detailed in IEC 60664-1

3.38

primary circuit

circuit electrically connected to the AC or DC supply input and external voltage transformers and current transformers

3.39**protective bonding**

electrical connection of accessible conductive parts or of protective screening to provide electrical continuity by means of connection to an external protective conductor which is securely returned to earth

3.40**protective bonding resistance**

resistance between the protective conductor terminal and a conductive part required to be connected to the protective conductor

3.41**protective conductor**

conductor provided for purposes of electrical safety

[SOURCE: IEC 60050-195:2021 195-02-09]

3.42**protective earthing****protective grounding, US**

earthing for purposes of protection against electric shock

[SOURCE: IEC 60050-195:2021, 195-01-11, modified – The term "electrical safety" has been replaced by "protection against electric shock".]

3.43**protective equipotential bonding circuit****PEB circuit**

circuit with a low impedance path from exposed-conductive-parts to extraneous-conductive-parts, to ensure equal potential throughout thus preventing a hazardous potential difference occurring between such parts in the event of a fault

Note 1 to entry: See Table A.1.

3.44**protective extra low voltage circuit****PELV circuit**

circuit in which the voltage cannot exceed the value of extra low voltage under normal conditions and under single fault conditions (except earth faults in other electric circuits)

Note 1 to entry: See Table A.1.

3.45**protective impedance**

impedance connected between live parts and accessible conductive parts, of such value that the current, under normal use and under likely fault conditions in the equipment, is limited to a safe value, and which is so constructed that the reliability is maintained throughout the life of the equipment

[SOURCE: IEC 60050-442:1998, 442-04-24, modified – In the definition, the term "exposed" has been replaced by "accessible", "in normal use" has been replaced by "under normal use", "electronic switch" has been replaced by "equipment".]

3.46**protective screening****protective shielding, US**

separation of electric circuits and/or conductors from hazardous-live-parts by an electrically protective screen connected to the protective earth

[SOURCE: IEC 60050-195:2021, 195-06-18, modified – In the definition, the words "equipotential bonding system and intended to provide protection against electric shock" have been replaced by "earth".]

3.47

protective separation

separation of one electric circuit from another by means of basic protection and fault protection

[SOURCE: IEC 60050-195:2021, 195-06-19]

3.48

rated impulse voltage

impulse voltage value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against transient overvoltages and to which clearances are referred

3.49

rated insulation voltage

RIV

voltage value assigned by the manufacturer to the equipment, or to a part of it, characterizing the specified (long-term) withstand capability of its insulation and to which dielectric voltage tests and creepage distances are referred

Note 1 to entry: The rated insulation voltage is not necessarily equal to the rated voltage of equipment which is primarily related to functional performance.

3.50

rated voltage

value of voltage assigned by the manufacturer, over the normal operating condition of a component, device or equipment

Note 1 to entry: Equipment may have more than one rated voltage value or may have a rated voltage range.

[SOURCE: IEC 60050-442:2014, 442-09-10, modified – In the definition, the term "rated value" has been replaced by "value", the term "to" has been replaced by "over the normal operating condition of", and at the end of the definition the words "and to which operation and performance characteristics are referred" and Note 2 to entry have been omitted.]

3.51

reinforced insulation

insulation that provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: Reinforced insulation can comprise several layers that cannot be tested singly as basic insulation or supplementary insulation.

[SOURCE: IEC 60050-195:2021, 195-06-09]

3.52

restricted access area

area accessible only to users with the proper authorization and knowledge of any safety hazards

[SOURCE: IEC 60050-195:2021, 195-04-04, modified – In the definition, the words "electrically skilled persons and electrically instructed persons" have been replaced by "users" and the words "and knowledge of any safety hazards" have been added.]

3.53

routine test

conformity test made on each individual equipment during or after manufacture

Note 1 to entry: Individual equipment includes complete products and spare parts.

[SOURCE: IEC 60050-151:2001, 151-16-17, modified – In the definition, the word "item" has been replaced by the word "equipment", and Note 1 to entry has been added.]

3.54

safety critical component

component which is relied upon for the integrity of its electrical insulation, mechanical strength, thermal, or flame-retardant properties during normal operation and single fault conditions, to prevent a safety hazard

3.55

safety extra low voltage circuit

separated extra low voltage circuit

SELV circuit

circuit in which the voltage cannot exceed the value of extra low voltage under normal conditions and under single fault conditions (including earth faults in other electric circuits)

3.56

screen

shield, US

conductive part that encloses or separates electric circuits and/or conductors

Note 1 to entry: See Table A.1.

3.57

single fault condition

condition in which there is a fault of a single protection (but not a reinforced protection) or of a single component or a device

Note 1 to entry: If a single fault condition results in one or more other fault conditions, all are considered as one single fault condition.

[SOURCE: IEC 60050-903:2013, 903-01-15]

3.58

solid insulation

material that provides electrical insulation between two opposite surfaces, not along an outer surface

3.59

supplementary insulation

independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation

[SOURCE: IEC 60050-195:2021, 195-06-07, modified – ", that provides fault protection" has been replaced by "in order to provide protection against electric shock in the event of a failure of basic insulation".]

3.60

tracking

progressive formation of conductive paths, which are produced on the surface or within a solid insulating material, due to the combined effects of electric stress and electrolytic contamination

Note 1 to entry: Tracking usually occurs due to surface contamination.

[SOURCE: IEC 60050-212:2010, 212-11-56]

3.61

type test

test of one or more devices made to a given design, to check if these devices comply with the requirements of the standard concerned

[SOURCE: IEC 60050-851:2008, 851-12-05]

3.62

user

person with the appropriate training and experience necessary to be aware of hazards to which they are exposed when accessing the equipment in a restricted access area and aware of measures to minimize a hazardous situation to themselves and other persons

3.63

wired network port

port for the connection of voice, data and signalling transfers intended to interconnect widely dispersed systems by direct connection to a single-user or multi-user communication network

Note 1 to entry: Examples of these include CATV, PSTN, ISDN, xDSL, LAN and similar networks.

Note 2 to entry: These ports may support screened or unscreened cables and may also carry AC or DC power (e.g. PoE) where this is an integral part of the telecommunication specification.

Note 3 to entry: A port generally intended for interconnection of components of a system under test (e.g. EIA-232, IEEE Standard 1284 (parallel printer), Universal Serial Bus (USB), IEEE Standard 1394 ("Fire Wire"), etc.) and used in accordance with its functional specifications (e.g. for the maximum length of cable connected to it), is not considered to be a wired network port.

Note 4 to entry: Optical fibre interfaces are considered as a wired network port. To achieve maximum power dissipation, it is important that the optical fibre ports are active when required during the safety assessment (during temperature rise testing, etc.)

3.64

withstand

ability of the equipment not to be damaged when imposed environmental or test conditions are applied (for example, impulse voltage)

3.65

working voltage

highest RMS value of the AC or DC voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

Note 1 to entry: Transients are disregarded.

Note 2 to entry: Both open-circuit conditions and normal operating conditions are taken into account.

[SOURCE: IEC 60050-581:2008, 581-21-19, modified – Notes 1 and 2 to entry have been added.]

4 Protection against electric shock

4.1 Protection from contact with hazardous-live-parts

4.1.1 General

Protection against direct contact with hazardous-live-parts shall be provided by adequate insulation, the equipment case or a barrier. Access to the equipment during installation, maintenance use, normal use and decommissioning shall be restricted to users aware of working procedures necessary to ensure safety.

The testing of components and equipment with regard to protection against electric shock shall be conducted as type tests and routine tests as defined in Clause 9.

Unearthed accessible conductive parts which can become hazardous live under a single fault condition shall meet the requirements of 4.1 to 4.10.

4.1.2 Insulation

Any conductive part that is not separated from the hazardous-live-parts by at least basic insulation shall be considered a live part. The insulation requirements shall be determined after consideration of the following influencing factors:

- rated insulation voltage of the circuit under consideration (see C.1.3);
- overvoltage category (see Annex B and Annex C);
- pollution degree (see Annex C);
- isolation class, for example, ELV, SELV, PELV, or PEB (see Annex A).

4.1.3 Equipment enclosure and barriers

The enclosure protection required by the product depends upon face and access level; minimum equipment enclosure requirements are detailed in Table 1.

Table 1 – Equipment enclosure requirements for protection against electric shock

Face	IP Code (IEC 60529:1989, IEC 60529:1989/AMD1:1999, IEC 60529:1989/AMD2:2013)	Requirements
Front panel, sides	IP2X or IPXXB	Hazardous-live-parts shall be located within the equipment enclosure or behind barriers such that they are not accessible under normal use. If a cover can be removed without the use of a tool, warning symbol 12 from Table 12 shall be visible.
Front panel connection(s)	IP2X	The front panel connections and terminal wiring, which are ELV, shall be accessible under normal use.
Top	IP4X	The top surfaces of barriers that are accessible in normal use shall provide ingress protection against falling objects, loose wires, washers, etc. Any such barriers shall have sufficient mechanical strength, stability and durability to maintain the specified degree of protection.
Bottom	IP4X	The bottom surfaces of barriers that are accessible in normal use shall provide ingress protection against loose wires, etc. Any such barriers shall have sufficient mechanical strength, stability and durability to maintain the specified degree of protection.
Rear	IP2X	Hazardous-live-parts shall be located within the equipment enclosure or behind barriers such that they are not accessible under normal use.
Rear panel connection(s)	IP1X	The rear connection panel, terminal wiring, under normal use shall be in a restricted access area and shall be IP1X or greater.
Corners	-	The corner shall have the highest IP taken from the adjacent sides.

Further requirements for accessible parts are detailed in 4.3.2.

Conformity with 4.1.3 is checked by applying the safety ingress requirements of IEC 60529:1989, IEC 60529:1989/AMD1:1999, and IEC 60529:1989/AMD2:2013.

4.1.4 Hazardous live terminations using stranded wire

The end of a stranded wire shall not be consolidated by soft soldering at places where the wire is subject to contact pressure, unless the method of clamping is designed so as to reduce the likelihood of a bad contact due to cold flow of the solder. Spring terminals that compensate for the cold flow are deemed to satisfy this requirement. Preventing the clamping screws from rotating is not considered to be adequate.

Terminals shall be located, guarded or insulated so that, should a strand of a flexible wire escape when the wire is fitted, there is no likelihood of accidental contact between such a strand and:

- accessible conductive parts; or
- unearthed conductive parts separated from accessible conductive parts by supplementary insulation only.

A loose strand of 8 mm length is normally considered for assessing this risk.

If the manufacturer determines that there is a risk, a recommendation shall be given in the documentation and a warning symbol 14 from Table 12 marked on the equipment. The risk can be eliminated, for example, by the use of an insulated crimp terminal or a single-strand wire.

Conformity with 4.1.4 is checked by inspection.

4.2 Protective impedance

A protective impedance shall limit the current or voltage to the levels of 4.3.3.2 in normal use and 4.10.4.1.2 in single fault condition.

Insulation between the terminations of the protective impedance shall meet the requirements of double insulation or reinforced insulation.

A protective impedance shall be one or more of the following:

- a) an appropriate single component which shall be constructed, selected and tested so that safety and reliability for protection against electric shock are assured. In particular, the component shall be:
 - 1) rated for twice the maximum working voltage;
 - 2) if a resistor, rated for twice the power dissipation for the maximum working voltage;
- b) a combination of components, for example, two Y rated capacitors in series, each rated for the total working voltage across the pair. Each capacitor shall have the same rated capacitance value and a withstand voltage rating of at least 2 000 V RMS, 1 min. This provides basic protection against electric shock in the case of a single fault condition.

Conformity with protective impedance can be demonstrated by application of the appropriate voltage test for double or reinforced insulation in Table C.8 to Table C.11 for a test site altitude of up to 2 000 m. For test site altitudes over 2 000 m, the test voltage should be adjusted in accordance with Table C.12.

Components, wires and connections shall be rated in accordance with the requirements for both normal use and appropriate single fault conditions. It is permissible for double insulation or reinforced insulation to be bridged by components meeting the requirement for protective impedance. Conformity of components with 4.2 and any associated basic insulation shall be checked after a single fault condition assessment or test according to 9.6.5.5. Any associated basic insulation shall be checked by assessment, measurement or testing in accordance with Annex C.

4.3 Accessible parts

4.3.1 General

Unless obvious, determination of whether a part is accessible, under normal use, shall be made as specified below and in 4.3.2.

Circuits intended to be connected to an external accessible circuit shall be considered as accessible conductive parts, for example wired network port.

Appropriate test fingers, as specified in 4.3.2.2, shall be applied without force unless a force is specified. Parts are considered to be accessible if they can be touched with a finger or pin, or if the covering does not provide suitable protection when touched under normal use (see below).

Where accessible conductive parts or circuits are separated from other parts by double insulation or reinforced insulation that is bridged by components in accordance with 4.2, the accessible parts or circuits shall comply with current limits in 4.3.3.2 for the normal use and 4.10.4.1.2 for a single fault condition. These requirements shall apply after dielectric voltage testing.

For hazardous-live-parts, a part is considered to be accessible if the test finger or pin reaches a point nearer to the hazardous-live-part than the applicable clearance for basic insulation at the rated impulse voltage determined from IEC 60664-1.

For equipment accepting plug-in modules, parts are considered to be accessible if they can be touched with the jointed test finger (see 4.3.2.2) up to a depth of 180 mm from the opening in the equipment.

Materials which can easily be damaged are not considered to provide suitable insulation (for example, lacquer, enamel, oxides and anodic films). Non-impregnated hygroscopic materials, such as paper, fibres and fibrous material are also not considered to provide suitable insulation.

A metallic accessible part is considered to be conductive if its surface is bare or is covered by an insulating layer which does not comply with the requirements of basic insulation.

4.3.2 Determination of accessible parts

4.3.2.1 General

If the user is intended to perform any actions in normal use, with or without the aid of a tool (a screwdriver, a coin, a key, etc.), which will increase the accessibility of parts, such actions shall be taken before performing the examinations of 4.3.2.2 to 4.3.2.3. Examples include:

- removing covers;
- adjusting controls;
- replacing consumable material;
- removing parts.

4.3.2.2 General examination

The jointed test finger (see IEC 61032 and IEC 60529:1989) shall be applied in every possible position. Where a part could become accessible by applying a force, the rigid test finger (see 6.2 of IEC 61010-1:2010 and of IEC 61010-1:2010/AMD1:2016) shall be applied with a force of 10 N. The force shall be exerted by the tip of the test finger so as to avoid wedge and lever action. The test shall be applied to all outer surfaces, including the bottom.

4.3.2.3 Openings for pre-set controls

A metal test pin 3 mm in diameter (force applied 10 N) shall be inserted through holes, in the equipment case, intended to give access to pre-set controls which require the use of a screwdriver or other tool. The test pin shall be applied in every possible direction through the hole; additional information can be found in IEC 61010-1. Penetration shall not exceed three times the distance from the equipment case surface to the control shaft or 100 mm, whichever is smaller.

4.3.2.4 ELV rated or live parts accessible when cover removed

If ELV rated or live parts, such as replaceable batteries or electromechanical relay contacts, are accessible when the cover is removed without the aid of a tool, then a warning label is required, visible when the cover is removed. This warning shall comprise symbol 14 and/or symbol 12 in Table 12.

4.3.2.5 Wiring terminals

Wiring terminals which are accessible under normal use, for example terminals on the front of a product, shall meet the requirement of Table 1.

Wiring terminals which are behind a panel, or in a restricted access area, and cannot be touched in normal use shall be deemed non-accessible. However, a protection of at least type IP1X according to 5.1 of IEC 60529:1989 shall be provided to prevent electric shock due to accidental contact.

If the protection is of type IP0X or IP1X, according to 5.1 of IEC 60529:1989, then the warning symbol 12 in Table 12 shall be used in the vicinity of accessible hazardous live wiring terminals.

Conformity with 4.3.1 to 4.3.2.5 shall be demonstrated by test.

4.3.3 Permissible limits for accessible parts

4.3.3.1 General

The voltage, current, charge or energy between an accessible part and reference test earth, or between any two accessible parts on the same piece of equipment (over a surface or through air), shall not exceed the values of 4.3.3.2 in normal use, nor those of 4.10.4.1.2 in single fault condition.

4.3.3.2 Values under normal use

Values under normal use are listed below. Voltages above the levels of a) are deemed to be hazardous live if any of the levels of b) or c) are exceeded at the same time.

a) Voltage levels: 30 V AC RMS or 60 V DC

For equipment rated for use in wet locations (either device or operator or both in wet locations due to rain, condensation, etc.), the voltage levels are 16 V AC RMS or 35 V DC.

b) Current levels under normal use: indicated in Table 2.

Table 2 – Current levels under normal use

Installation location	Figure 3 or Figure 4 of IEC 60990:2016 Measurement circuit to be used	Sinusoidal waveforms	Non-sinusoidal or mixed frequency waveforms	
		mA RMS	mA peak	mA DC
Dry	Figure 4	0,5	0,7	2
Wet	Figure 3 with $R_S = 375 \Omega$ (instead of $1\,500 \Omega$)	0,5	0,7	2
Dry	Figure 3 with $R_B = 75 \Omega$ Relates to possible burns in the frequency range 30 kHz to 500 kHz	70	-----	-----

- c) After switching off the equipment, capacitors shall be discharged within 5 s to a residual charge in Table 3 or to a voltage of 20 V or less. In the case of installed equipment, where the voltage at the plug-and-socket devices can be touched and these devices can be pulled out when live, without the use of tools, the capacitors shall be discharged within 1 s.

With respect to the above two discharge cases, verification shall be by calculation of the energy in the total in-circuit capacitance, or measurement of the voltage, 5 s or 1 s after switching off the equipment.

If the above parameters cannot be complied with, due to design constraints, there shall be an easily observable warning on the equipment that such capacitors should be safely discharged during decommissioning (symbol 14 from Table 12).

Table 3 – Charge or energy of capacitance levels under normal use

Maximum level	For peak or DC voltages
45 μC	Up to 15 kV
350 mJ	$\geq 15 \text{ kV}$
NOTE Figure 3 of IEC 61010-1:2010 shows the maximum acceptable voltage for the capacitance value for both normal use and single fault condition.	

4.4 Earthing and protective bonding requirements

4.4.1 General

Earthing in equipment may be required for reasons of personnel safety or to reduce the effects of electromagnetic interference. Where there is any conflict between these two requirements, personnel safety shall always take precedence. The acceptable arrangement of protective means against electric shock is illustrated in Figure 4 of IEC 61010-1:2010.

4.4.2 Insulation between live parts and accessible conductive parts

Accessible conductive parts shall be bonded to the protective earth conductor terminal if they could become hazardous live in the case of a single fault of the primary protective means specified in 4.1. Alternatively, such accessible parts shall be separated from parts which are hazardous live by a conductive protective screen or barrier bonded to the protective earth conductor terminal. For measuring and protection equipment, indirect bonding is permitted as an alternative to direct bonding.

Unearthed accessible conductive parts such as equipment doors or flaps, handles, etc. need not be bonded to the protective earth conductor if they are separated from all hazardous-live-parts by double insulation or reinforced insulation.

Equipment of protective class I shall have a minimum of basic insulation between the accessible conductive parts bonded to protective earth conductor and live parts, provided that the insulation cannot be reduced to less than basic insulation by any single fault including

mechanical impact, loose wires and terminals, etc. Mechanical retention can be used to ensure maintenance of basic insulation under a single fault condition. Screws or nuts with lock washers are not regarded as liable to become loose, nor are wires which are mechanically secured by more than soldering alone.

Verification shall be made by measurement, where there is any doubt of conformity.

4.4.3 Protective bonding

4.4.3.1 General

Accessible conductive parts shall be bonded to the protective conductor; it is not, however, essential when one of the following applies.

- Unearthed accessible conductive parts are exclusively related to electrical circuits with automatic disconnection of supply, or with current or voltage limiting in case of direct contact according to 4.3, and the voltage does not exceed ELV limits (see Annex A).
- The unearthed accessible conductive parts are of small dimensions, in normal use are not intended to be grasped, have a low probability of contact, and are separated from hazardous-live-parts by at least basic insulation.

Additional information for the acceptable arrangement of protective bonding against electric shock can be found in IEC 61010-1:2010, Figure 4.

4.4.3.2 Bonding of parts connected to the protective conductor

The equipment design shall ensure that any painting or coating of surfaces within the protective earth bonding circuit does not affect the protective bonding resistance of that circuit.

See 9.6.4.5 for protective bonding test requirements.

4.4.3.3 Protection against corrosion

Conductive parts in contact at protective earthing terminals and connections shall be chosen to minimize electro-chemical corrosion between materials in any working, storage or transport environment conditions as specified in the instructions supplied with the equipment.

Corrosion resistance can be achieved by a suitable plating or coating process.

Conformity with 4.4.3.3 is tested by applying the conducted damp-heat, steady state type test (including protective bonding test requirements given in 9.6.4.5).

4.4.3.4 Interruption of protective bonding

Where the protective bonding to a subassembly of equipment is made by a plug-and-socket device when it is live or conducting, the protective bonding shall not be broken before the live conductors. On re-connection, the protective bonding shall re-connect before the live conductors or, at the latest, together with the live conductors.

Conformity is checked by inspection and/or test.

4.5 Functional earthed circuits

If functional earthing of accessible parts is necessary, the following apply.

- It is permitted to connect the functional earthed circuit to a protective conductor terminal or to a protective bonding conductor.
- The functional earthed circuit shall be separated from ELV circuits by at least basic insulation.

- The functional earthed circuit shall be separated from PEB and PELV circuits by at least functional insulation.
- The functional earthed circuit shall be separated from parts at hazardous voltage in the equipment by either:
 - double insulation or reinforced insulation; or
 - a protectively earthed screen or another protectively earthed conductive part, separated from parts at hazardous voltages by at least basic insulation.

Conformity is checked by inspection, measurement and test.

4.6 Protective conductor connection

Equipment with internal protective bonding shall have means of connection for the external protective conductor, preferably near to the terminals for the respective live conductors.

The protective conductor terminal shall be corrosion-resistant. It shall be capable of accommodating cables of at least the same cross-sectional area as the equipment circuit with the highest current or protection element rating which can cause an earth fault.

The means of connection for the protective conductor shall not be used as a part of the mechanical assembly of the equipment.

Conformity is checked by inspection.

4.7 High leakage current

Where equipment has a continuous leakage current of more than 3,5 mA AC RMS or 10 mA DC in normal use, the protective conductor shall be connected as for permanently connected equipment (see Clause E.2); this shall be stated in the equipment documentation.

Any current measurements shall be performed using the measuring circuit in Figure 4 of IEC 60990:2016. The equipment shall be isolated from earth and from the measuring circuit connected between the protective conductor terminal and the protective conductor.

Conformity is checked by measurement.

4.8 Solid insulation

4.8.1 General

Solid insulation shall be designed to resist the mechanical, electrical, thermal, climatic, and other stresses that are to be expected under normal use throughout the life of the equipment.

Solid insulation shall be designed to withstand mechanical vibration or shock which can be expected during transportation, storage and installation. Conformity with the requirements in 4.8.2 shall be checked after the mechanical tests in 9.6.2.1 and 9.6.2.2.

Wire insulation shall be considered as solid insulation.

Thin, easily damageable materials, such as coating with lacquer or oxides and anode coatings, are considered insufficient to satisfy these requirements.

Conformity with 4.8 is checked by inspection, measurement and test.

4.8.2 Requirements

The maximum temperature of the solid insulation, under normal use at maximum ambient temperature, shall be less than the temperature given for the appropriate class in Table 8 or by 6.10.2.

Conformity of solid insulation shall be verified by performing dielectric voltage and impulse withstand type tests, according to the relevant rated working voltage and overvoltage category, determined from the appropriate Table C.2 to Table C.11, and Table C.12. The test method shall be performed according to the method detailed in 9.6.4.2 and 9.6.4.3. The test proves the minimum distance through the insulation, not the creepage distance across the surface of the insulation.

4.9 Clearances and creepage distances

4.9.1 General

Clearance and creepage distances shall be determined from the appropriate Table C.2 to Table C.11, the clearance and creepage distances can be interpolated for voltages above 300 V.

The minimum creepage distance shall not be less than the minimum clearance in air. These clearances and creepage distances are minimum values; manufacturing tolerances shall additionally be taken into account.

Examples for design and measurement of clearances and creepage distances are given in 6.2 of IEC 60664-1:2020.

Inhomogeneous fields generally apply to equipment.

For the functional insulation of pulsating voltage waveforms, the RMS voltage of the waveform shall be calculated and used as the working voltage in the determination of the required clearances and creepage distances. The amplitude of repetitive peak voltages of short duration (defined as being less than 2 % of the waveform cycle duration) should not exceed 175 % of the rated RMS working voltage used to determine the minimum creepage distance.

Where there is any doubt that the required clearance and creepage distances are compliant, measurements shall be made.

If appropriate, type tests and routine testing of clearances shall be carried out to determine conformity with 4.9, in accordance with Clause 9.

4.9.2 Clearances

4.9.2.1 General

Clearances are specified to withstand the maximum transient overvoltage that can be present on the circuit, either as a result of an external event (such as a lightning strike, or a switching transient), or as the result of the operation of the equipment. Clearances shall be determined with reference to Annex A and Annex C. For clearances in primary circuits, Table B.1 should also be referred to.

The clearance distance between any two circuits shall be based on the maximum transient overvoltage originating from either circuit.

In order to maintain product safety, the clearances for equipment at altitudes greater than 2 000 m shall be multiplied by the factor given in Table 4.

Table 4 – Altitude multiplication factor

Altitude metres	Clearance multiplying factor
2 000	1,00
3 000	1,14
4 000	1,29
5 000	1,48

For test site altitudes other than 2 000 m, the corresponding correction factors of the test voltage are given in Table C.12. If necessary, take appropriate measures to limit the transient voltages the equipment is subjected to; for example, use of spark gaps or transient suppressors.

4.9.2.2 Clearances for primary circuits

The clearances in air relating to primary circuits are determined by the rated impulse voltage (refer to C.1.4).

Basic insulation is the minimum requirement between primary circuits and other circuits, (primary or non-primary circuits) including accessible parts and earthed parts. Additional insulation (for example, functional or supplementary insulation) may be required, depending upon the isolation class (see Annex A). The design of functional insulation, such as that across a primary circuit, shall be such that the risk of fire is minimized.

The clearance values are stated in Annex C. For rated voltages and installation categories other than those given in Annex C tables, refer to IEC 60664-1:2020, Annex F.

NOTE The withstand voltages in Table C.2 to Table C.11 are for inhomogeneous fields. In many cases, the clearance in air between two parts of the equipment is between inhomogeneous and homogeneous; hence, clearances can be proven by testing.

4.9.2.3 Clearances for non-primary circuits

Clearances for non-primary circuits shall withstand the maximum transient overvoltage that can be present on the circuit. If transient overvoltages cannot occur, clearances are based on the rated working voltage.

The clearance values are stated in Annex C. For impulse or working voltages other than those given in Annex C tables, refer to Annex A of IEC 60664-1:2020.

4.9.3 Creepage distances

It is assumed that the equipment within the scope of this document is subject to continuous voltage stress over a long period, requiring the design of appropriate creepage distances.

Creepage distances shall be determined with reference to Annex A and Annex C.

Examples for design and measurement of creepage distances are given in 5.2 and 6.2 of IEC 60664-1:2020.

The creepage distance between any two circuits shall be based on the maximum working voltage across this creepage distance (typically sum of the voltages from these circuits).

If pollution degree 3 or 4 causes persistent conductivity, for example, due to carbon or metal dust, the dimensions for creepage distances cannot be specified. Instead, the surface of insulation shall be designed to avoid a continuous path of conductive pollution (for example, by means of ribs or grooves, as determined by 5.2.5 of IEC 60664-1:2020).

Table C.13 indicates additional protection which may be used to reduce the pollution degree within the equipment. If Table C.13 is used to determine reduced creepage distance, it should be ensured that this is not less than the minimum allowed clearance.

Conformity of creepage distances with 4.9.3 shall be verified by measurement in the case of doubt. It cannot be verified by voltage withstand testing.

Interpolation of creepage distances in Annex C tables is permitted, for both primary and non-primary circuits.

4.10 Single fault conditions

4.10.1 Testing in single fault condition

The equipment shall not present a risk of electric shock or fire after a single fault test. It is not required that a single fault condition is applied to double or reinforced insulation. It need not be functional after the test.

The following requirements apply.

- The fault conditions which are liable to result in electric shock or fire hazards, as generally evidenced by examination of the equipment and its circuit diagram, shall be applied.
- Fault tests shall be made except where it can be demonstrated that it is improbable that a hazard will arise from a particular single fault condition.
- The equipment shall be operated under the least favourable combination of reference test conditions.

These conditions include worst-case tolerance of rated voltage and current, worst-case equipment orientation, whether covers or other removable parts are not fitted during normal use, maximum specified external fuse rating.

NOTE Small parts, such as screws and rivets which are not accessible and are isolated from HLV circuits by at least basic insulation, are not taken into consideration.

Subclause 6.10 provides an alternative to testing for protection against spread of fire under a single fault condition but is not applicable to electric shock hazards.

4.10.2 Application of single fault condition

4.10.2.1 General

Single fault conditions shall be applied one at a time and shall be applied in turn in the most convenient order. Multiple simultaneous faults shall not be applied; they can, however, result from the application of a single fault. The application of a single fault can result in the equipment being in a hazardous state and the test personnel should take appropriate precautions such as the use of safety screens.

After the application of a single fault condition, the equipment or relevant part shall meet the requirements of 4.10.4.

Single fault condition assessment shall include the following.

4.10.2.2 Protective impedance

The following requirements apply.

- If protective impedance is formed by a combination of components, each component shall in turn be short-circuited or disconnected.

- If protective impedance is formed by a combination of basic insulation and a voltage- or current-limiting device, both the basic insulation and the voltage- or current-limiting device shall be subjected to single faults, applied one at a time. Basic insulation shall be short-circuited. The voltage- or current-limiting device shall be short-circuited or disconnected, whichever is less favourable.

Parts of a protective impedance which are high-integrity components need not be short-circuited or disconnected.

4.10.2.3 Transformers

Transformer non-primary windings and sections of tapped windings, which are loaded under normal use shall be tested in turn, one at a time, to simulate short circuits in the load. All other windings are loaded or not loaded, whichever load condition is less favourable.

The primary and non-primary windings of the transformer shall have a short circuit applied between them unless separated by reinforced or double insulation. The reinforced or double insulation shall be tested where thermal damage to the insulation can create a risk of electric shock.

Short circuits shall also be made on the load side of any current-limiting impedance or over-current protective device which is connected directly to the winding.

4.10.2.4 Outputs

Outputs shall be short-circuited one at a time.

4.10.2.5 Insulation between circuits and parts

Functional insulation between circuits and parts shall be short-circuited where this could cause overheating of any material creating a risk of fire, unless that material is of flammability class V-1 or better of IEC 60695-11-10.

Basic insulation in primary circuits shall be bridged to check against the spread of fire.

Supplementary, reinforced and double insulation need not be short-circuited. The exception to this is where thermal damage to the insulation can create a risk of electric shock.

4.10.2.6 Primary circuits and hazardous voltage non-primary circuits

Single fault conditions shall be applied by open-circuiting or short-circuiting components in primary circuits and hazardous voltage non-primary circuits, within the equipment, where these can create a risk of electric shock or fire.

4.10.2.7 Overloads

Single fault conditions shall be applied where a circuit or component overload can create a fire or electric shock hazard. This includes connection of the most unfavourable load impedances to terminals and connectors which deliver power or signal outputs from the equipment.

It is permitted to use fusible links, overcurrent protection devices and the like to provide adequate protection.

Where there are multiple ports with the same internal circuitry, the single fault test can be limited to one port only.

4.10.2.8 Intermittently rated resistors

Continuous dissipation in resistors designed for intermittent dissipation shall be considered under the single fault condition assessment.

4.10.2.9 DC inputs

DC inputs shall be assessed for effects of reverse polarity under worst case conditions.

It is permitted to use fusible links, overcurrent protection devices and the like to provide adequate protection.

Where there are multiple ports with the same internal circuitry, the test can be limited to one port only.

4.10.3 Duration of tests

The equipment shall be operated until further change as a result of the applied fault is unlikely. Each test is normally limited to one hour since a secondary fault arising from a single fault condition will usually manifest itself within that time. If there is an indication that a risk of electric shock, spread of fire or injury to persons can eventually occur, for example if the temperature has not stabilized, the test shall be continued for a maximum period of four hours unless a hazard occurs before then.

4.10.4 Compliance

4.10.4.1 Conformity with requirements for electric shock protection

4.10.4.1.1 General

A dielectric voltage withstand test according to 9.6.4.3 shall be performed before and after a single fault test to demonstrate that the equipment does not present an electric shock hazard following the application of a single fault condition.

PEB, PELV and SELV circuits shall remain safe to touch after the application of a single fault condition.

Following a single fault condition, accessible parts shall not be hazardous live, as defined in 4.10.4.1.2.

4.10.4.1.2 Values in single fault condition

Values in single fault conditions are given below. Voltages above the levels of a) are deemed to be hazardous live if any of the levels of b) or c) are exceeded at the same time.

a) Voltage levels are 50 V AC RMS or 120 V DC

For voltages of short duration, the duration versus voltage levels are those of Figure 2 of IEC 61010-1:2010/AMD1:2016, measured across a 50 kΩ resistor.

For equipment rated for use in wet locations, the voltage levels are 33 V AC RMS or 70 V DC

b) Current levels are as shown in Table 5.

Table 5 – Current levels in single fault condition

Installation location	Figure 3 or Figure 4 of IEC 60990:2016 Measurement circuit to be used	Sinusoidal waveforms	Non-sinusoidal or mixed frequency waveforms	mA DC
		mA AC RMS	mA AC peak	
Dry	Figure 4	3,5	5	15
Wet	Figure 3 with $R_S = 375 \Omega$ (instead of $1\,500 \Omega$)	3,5	5	15
Dry	Figure 3 with $R_B = 75 \Omega$ Relates to possible burns in the frequency range 30 kHz to 500 kHz	500	-----	-----

c) The capacitance level is that defined in Figure 3 in IEC 61010-1:2010.

4.10.4.2 Conformity with requirements for temperature protection

Refer to 6.3.1.

4.10.4.3 Conformity with requirements for protection against the spread of fire

Refer to 6.10.3.

4.10.4.4 Conformity with requirements for hazardous gases and chemicals

Refer to 6.3.2.

4.10.4.5 Conformity with requirements for mechanical protection

Conformity with requirements for mechanical protection is checked by inspection to ensure that no parts are expelled from the equipment due to parts exploding or imploding and that no mechanical hazard is caused by the application of a single fault condition.

The means of protection against expelled parts should not be removable without the aid of a tool. If the protection is removable without the use of a tool, symbol 14 from Table 12 shall be used, and an appropriate warning provided in the documentation.

5 Mechanical aspects

5.1 Protection against mechanical hazards

5.1.1 Stability

Under conditions of normal use, equipment shall not become physically unstable to the degree that it could become a hazard to the user.

Conformity of stability is checked by inspection.

5.1.2 Moving parts

Moving parts shall not be able to crush, cut or pierce parts of the body of the user likely to come into contact with them, nor severely pinch the user's skin under normal use and maintenance use. This requirement does not apply to easily touched moving parts which are obviously intended to operate on parts of materials external to the equipment, for example tripping mechanism. Such equipment should be designed to minimize inadvertent touching of such moving parts (for example, by fitting of guards, handles, etc.).

Conformity of moving parts is checked by inspection.

5.1.3 Edges and corners

All easily touched edges, projections, corners, openings, guards, handles and the like of the equipment case should be smooth and rounded so as not to cause injury during normal use.

Conformity of edges and corners is checked by inspection and, if necessary, by application of an object that represents a finger in size, shape and hardness, to check for abrasions and cuts.

NOTE An acceptable procedure that can be used is outlined in UL 1439.

5.2 Mechanical requirements

The equipment shall, when mounted in accordance with the manufacturer's instructions, comply with the mechanical tests in 9.6.2.1 to 9.6.2.4.

Where higher severity levels are required, they shall be agreed between the manufacturer and the user.

5.3 Mechanical security of terminations

Refer to Annex E.

6 Flammability and resistance to fire

6.1 General

This Clause 6 provides methods and procedures to reduce the risk of fire associated with the equipment to a safe level, by one of the following means:

- eliminating or reducing the sources of ignition within the equipment.
- reducing the amount of combustible (or flammable) materials within the equipment;
- containment of a fire within the equipment, should it occur.

6.2 Requirements for protection against the spread of fire

It is possible that equipment or parts of equipment cause excessive temperatures, under normal use or single fault condition, which could lead to a risk of fire within the equipment or to its surroundings.

In order for a risk of fire within the equipment to exist, all three of the following basic elements shall exist:

- 1) The equipment circuits have sufficient power or energy to be an ignition source.
- 2) There is oxygen present (air is about 21 % oxygen).
- 3) There are combustible materials present to support the combustion process.

The use of the methods and procedures within this Clause 6 offers the following benefits:

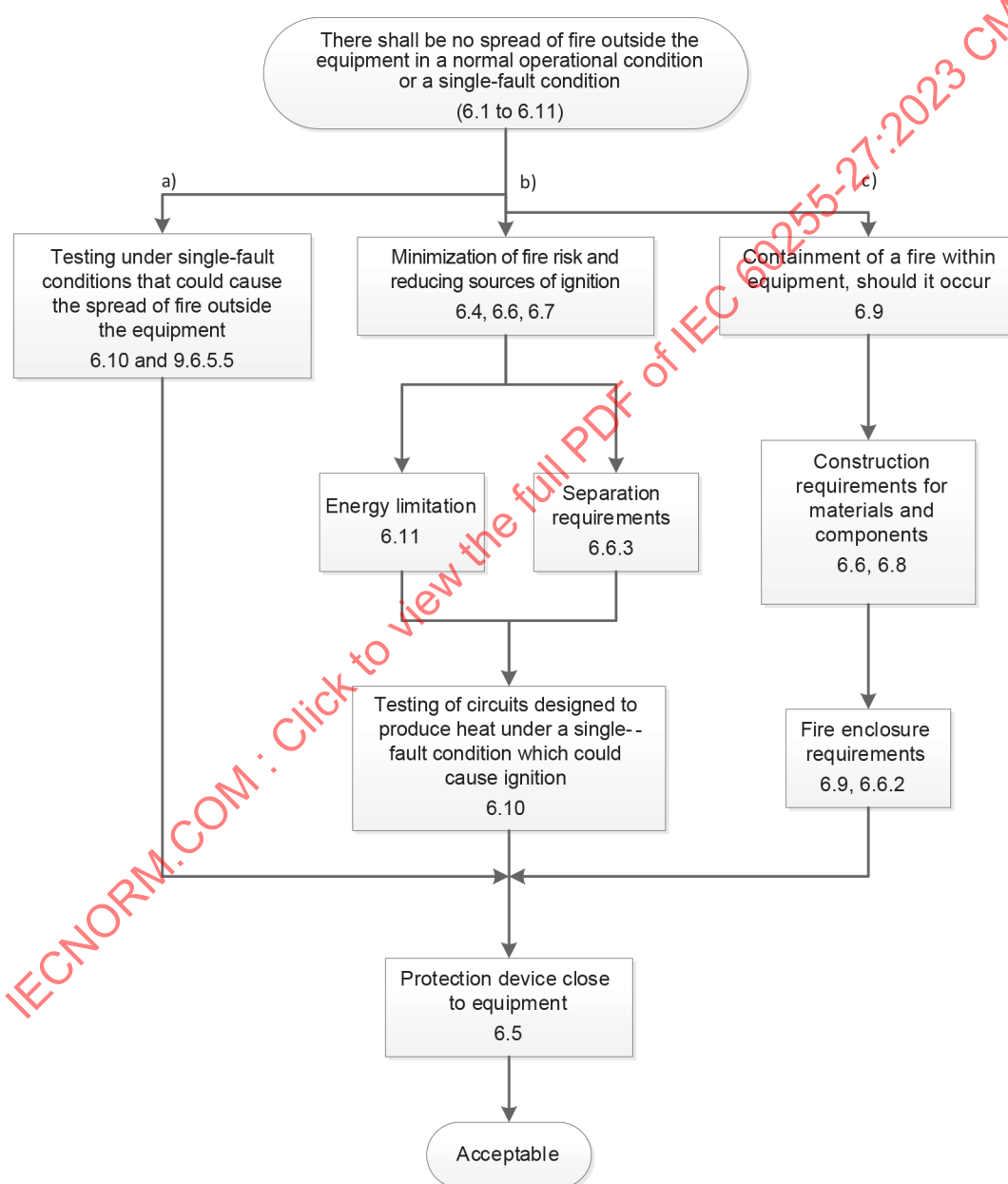
- conformity with fire-protection requirements without tests;
- reduction of single fault condition testing;
- specification of construction methods which allow verification of fire protection by inspection;
- reduction of interpretation differences and testing variables between inspection authorities.

This Clause 6 also details requirements for protection against the spread of fire, maximum temperature limits and limited energy circuits (see 6.11).

There shall be no spread of fire outside the equipment in normal use or in single fault condition. Figure 1 is a flow chart showing methods of conformity verification.

Conformity is checked against the requirements for a protection device (see 6.5) and by at least one of the following methods.

- a) Testing in the single fault conditions (see 6.10 and 9.6.5.5) that could cause the spread of fire outside the equipment. The conformity criteria of 6.10.3 shall be met.
- b) Verifying elimination or reduction of the sources of ignition within the equipment as specified in 6.4.1 and 6.4.2 or 6.4 and 6.11.
- c) Verifying, as specified in 6.9, that if a fire occurs it will be contained within the equipment.



IEC

Figure 1 – Flow chart showing requirements for protection against the spread of fire

6.3 General hazards from overheating and fire

6.3.1 Surface temperature limits for protection against burns

Heating shall not cause a hazard under normal use or single fault conditions, nor shall it cause spread of fire outside the equipment. Table 6 specifies the maximum acceptable temperatures under normal use at maximum ambient temperature. The temperatures in Table 6 can be exceeded under the following conditions.

- For areas unlikely to be touched, with no dimension exceeding 50 mm, 100 °C is allowable.
- Temperatures exceeding the limits, which are for an ambient temperature of 40 °C, are permitted provided that unintentional contact is unlikely and the part has a warning indicating that it is hot, for example, symbol 13 (or 14) of Table 12.

Refer to 4.10 for the maximum acceptable temperatures under a single fault condition.

If easily touched heated surfaces are necessary for functional reasons, they are permitted to exceed the values in Table 6, but shall be recognizable as such by appearance or function or shall be marked. Symbol 13 of Table 12 should be used to indicate that a surface or part is hot.

**Table 6 – Maximum temperature under normal use
and at an ambient temperature of 40 °C**

Accessible parts under normal use	Maximum temperature °C	
	Metal	Non-metallic
Handles, knobs, grips, etc. held or touched for short periods only	60	85
Handles, knobs, grips, etc. continuously held under normal use	55	70
External surfaces of equipment which can be touched	70	80
Parts inside the equipment which can be touched	70	80

Conformity with 6.3.1 is checked by measurement and by inspection of guards and covers, to check that they protect against accidentally touching surfaces that are at temperatures above the values in Table 6. All guards and covers shall be in place when conducting the test. If the guards or covers can be removed without the aid of a tool, symbol 13 or symbol 14 of Table 12 shall be used.

6.3.2 Hazardous gases and chemicals

The equipment shall not liberate hazardous amounts of poisonous or injurious gases under normal operation.

The manufacturer's documentation shall state which potentially poisonous or injurious gases can be liberated, and the quantities.

Conformity is checked by inspection of the manufacturer's documentation. The wide variety of gases makes it impossible to specify conformity tests based on limit values, so reference should be made to tables of occupational threshold limit values.

6.4 Minimization of fire risk

6.4.1 General

The minimization of fire risk, both within the equipment and to cabling and wiring, shall be a major consideration. Protection consistent with reliability and operational requirements shall be provided.

In the event of a single fault condition, any damage shall be contained within the equipment (see 6.10).

Components and materials shall be chosen and used so that there is negligible risk of a fire being caused due to component failure or possible short circuit.

Safety critical components of primary circuits and circuits exceeding ELV voltage limits should comply with relevant component standards; refer to Annex D for information. The equipment and its circuit diagrams shall be examined to determine if single fault condition tests are necessary to demonstrate that there is a negligible risk of fire.

6.4.2 Eliminating or reducing the sources of ignition within the equipment

6.4.2.1 General

The risk of ignition and occurrence of fire is reduced to a tolerable level if one of the following requirements is met for each source of ignition hazard.

6.4.2.2 Limited power

The voltage, current and power available to the circuit or part of equipment are limited as specified in 6.11. Conformity is checked by measurement of limited-energy values as specified in 6.11.

6.4.2.3 Basic insulation

Insulation between parts at different potentials shall meet the requirements for basic insulation, or it shall be demonstrated that short-circuiting the insulation will not cause ignition. Conformity is checked by inspection or by the relevant tests of 9.6.5, applying the criteria of 6.10.

6.4.2.4 Ignition sources

Circuits of the equipment which cannot be classified as limited-energy circuits (see 6.11) are considered ignition sources, in which case conformity is checked by the relevant tests of 9.6.5, applying the criteria of 6.10.

6.5 Cabling and fusing

The manufacturer shall recommend the following to minimize the risk of fire and thermal overload of the AC or DC supply and protective conductors or other equipment fed by the product, taking into account worst-case single fault conditions.

- Connection cables: minimum cross-section and voltage rating.
- Protection devices: fuse or circuit-breaker rating; it should be close to the equipment and should include the protection device characteristic and voltage rating.

NOTE Failures or faults can be due to short circuits within the equipment or to accessible conductive parts, earth faults, short circuit in the output circuits, or control circuit failure. Cabling and fusing is of importance when:

- under use as intended, a fault in the equipment can cause the rated output current of the equipment to be exceeded, resulting in thermal overload of the protective conductor or other equipment fed by the equipment; and
- the equipment fault does not automatically cause a disconnection to its AC or DC supply.

6.6 Flammability of materials and components

6.6.1 General

See Table 14 for the test overview, including flammability.

Conformity is checked by inspection of data on materials, or by performing the flammability tests specified in IEC 60695-11-10 on three samples of the relevant parts (see Table 14 and 9.6.5 of this document). The samples may be any of the following:

- a) complete parts and assemblies of materials as used in product;
- b) sections of a part, including the area with the least wall thickness and any ventilation openings;
- c) samples in accordance with IEC 60695-11-10.

Where safety is involved, components shall meet one of the following:

- the flammability requirements of a relevant IEC component standard which includes such requirements;
- where no relevant IEC standard exists, the flammability requirements of this document;
- applicable flammability requirements of a non-IEC standard where these are at least as high as those of the relevant IEC standard, provided that the component has been approved to the non-IEC standard by a recognized testing authority.

6.6.2 Materials for components and other parts inside fire enclosures

Materials for use within fire enclosures shall comply with any of the following.

- a) Electrical components which do not present a fire hazard under abnormal operating conditions when tested according to 4.10.
- b) Materials and components within an equipment case of volume 0,06 m³ or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas.
- c) One or more layers of thin insulating material, such as adhesive tape, used directly on any surface within the fire enclosure, including the surface of current-carrying parts, provided that the combination of the thin insulating material and the surface of application comply with the requirements of flammability class V-2, or better, of IEC 60695-11-10. Where the thin insulating material is on the inner surface of the fire enclosure itself, the requirements for fire enclosure construction in 6.9 apply.
- d) Electronic components, such as integrated circuit packages, opto-coupler packages, capacitors and other small parts mounted on material of flammability class V-1, or better, of IEC 60695-11-10.
- e) Wiring, cables and connectors insulated with PVC, TFE, PTFE, FEP or neoprene or polyimide or insulated wire that retards flame propagation, as determined by conformity with the recommended performance requirements in the applicable parts of IEC 60332.

NOTE Wire with a flammability RATING of UL 2556 VW-1 or equivalent is considered to meet this requirement.

- f) Individual clamps (not including helical wraps or other continuous forms), lacing tape, twine and cable ties used with wiring harnesses.

Conformity with 6.6.1 and 6.6.2 is checked by inspection of the equipment and material data sheets.

6.6.3 Materials for fire enclosures

Materials for components which fill an opening in a fire enclosure, and which are intended to be mounted in that opening shall:

- be of flammability class V-1, or better, of IEC 60695-11-10; or
- pass the flammability test of IEC 60695-11-10; or
- comply with the flammability requirements of the relevant IEC component standard.

NOTE Examples of these components are fuse-holders, switches, connectors and appliance inlets.

Plastic materials of a fire enclosure shall be located more than 13 mm through air from arcing parts such as unenclosed switch contacts.

Plastic materials of a fire enclosure located less than 13 mm through air from non-arcing parts which, under any condition of normal or abnormal operation, could attain a temperature sufficient to ignite the material, shall be capable of passing the test of IEC 60695-2-20. The average time to ignition of the samples shall be not less than 15 s. If a sample melts through without igniting, the time at which this occurs is not considered to be the time to ignition.

Conformity with 6.6.3 is checked by inspection of the equipment and material data sheets and, if necessary, the appropriate flammability test.

6.6.4 Materials for components and other parts outside fire enclosures

Except as otherwise noted below, materials for components and other parts (including mechanical enclosures, electrical enclosures and decorative parts), located outside fire enclosures, shall have a minimum flammability class HB75 according to IEC 60695-11-10 if the thinnest significant thickness of this material is < 3 mm, or flammability class HB40 according to IEC 60695-11-10 if the thinnest significant thickness of this material is ≥ 3 mm, or flammability class HBF. Where a mechanical or an electrical enclosure also serves as a fire enclosure, the requirements for fire enclosures apply (see 6.6.3 and 6.9).

The above flammability requirements do not apply to any of the following:

- a) electrical components which do not present a fire hazard under abnormal operating conditions when tested according to 4.10;
- b) components meeting the flammability requirements of a relevant IEC component standard which includes such requirements;
- c) electronic components, such as integrated circuit packages, opto-coupler packages, capacitors and other small parts that are:
 - 1) mounted on material of flammability class V-1, or better, of IEC 60695-11-10;
 - 2) supplied from a power source of no more than 15 VA, or that complies with limited-energy circuit requirements (see 6.11), under normal operating conditions or after a single fault in the equipment and mounted on material of flammability class HB75 according to IEC 60695-11-10 if the thinnest significant thickness of this material is < 3 mm, or flammability class HB40 according to IEC 60695-11-10 if the thinnest significant thickness of this material is ≥ 3 mm.

Connectors shall comply with one of the following:

- be made of material of flammability class V-1, or better, of IEC 60695-11-10;
- pass the tests of IEC 60695-11-10;
- comply with the flammability requirements of the relevant IEC component standard;
- be located in a secondary circuit supplied by a power source that is limited to a maximum of 15 VA or that complies with limited-energy circuit requirements (see 6.11) under normal operating conditions and after a single fault in the equipment (see 4.10).

Terminal blocks shall comply with the following:

- be made of material of flammability class V-1, or better, of IEC 60695-11-10;
- comply with the temperature limits for the relevant material with maximum load current applied.

6.7 Fire ignition sources

All circuits of equipment which can be classified as including primary circuits or circuits exceeding ELV voltage limits shall be considered to be an ignition source of fire. All electrical components of such circuits are considered likely to be an ignition source of fire.

6.8 Conditions for a fire enclosure

6.8.1 Parts requiring a fire enclosure

The following are considered to have a risk of ignition and therefore require a fire enclosure:

- a) components in primary circuits or exceeding ELV voltage limits. Except where equipment meets the requirements of all the applicable single fault tests of 4.10;
- b) components in non-primary circuits supplied by power sources which exceed the limits specified in 6.11;
- c) components in non-primary circuits supplied by a source complying with limited-energy circuits as specified in 6.11, but not mounted on material of flammability class V-1, or better, of IEC 60695-11-10;
- d) components within a power supply unit or assembly having an output complying with a limited-energy circuit, as specified in 6.11, including overcurrent protective devices, limiting impedances, regulating networks and wiring (see 6.8.2 for exceptions), up to the point where the source output criteria for a limited-energy circuit are met;
- e) components having unenclosed arcing parts, such as open switch and relay contacts in a circuit at hazardous voltage or at a hazardous energy level;
- f) insulated wiring, except as permitted in 6.8.2.

6.8.2 Parts not requiring a fire enclosure

The following do not require a fire enclosure:

- a) motors;
- b) transformers;
- c) electromechanical components complying with 6.6;
- d) components, including connectors, meeting the requirements of 6.6.4, which fill an opening in a fire enclosure;
- e) wiring and cables insulated with PVC, PTFE, TFE, FEP, neoprene or polyimide;
- f) plugs and connectors forming part of a power supply cord or interconnecting cable;
- g) connectors in non-primary circuits supplied by power sources which are limited to a maximum of 15 VA under normal operating conditions and after a single fault in the equipment;
- h) connectors in non-primary circuits supplied by limited-energy circuits complying with 6.11;
- i) other components in non-primary circuits:
 - 1) supplied by a limited-energy circuit complying with 6.11 and mounted on materials of flammability class V-1 or better, of IEC 60695-11-10;
 - 2) supplied by internal or external power sources which are limited to a maximum of 15 VA under normal operating conditions and after a single fault in the equipment and mounted on material having a minimum flammability class HB75 according to IEC 60695-11-10, if the thinnest significant thickness of this material is < 3 mm or flammability class HB40 according to IEC 60695-11-10 if the thinnest significant thickness of this material is ≥ 3 mm;
- j) equipment which has had all the applicable single fault tests of 4.10 applied to both the primary and non-primary circuits;
- k) small parts, such as paper labels, up to 1 500 mm².

If the components become excessively hot under a single fault condition and are mounted within 13 mm of non-metallic materials of V-2 rating or worse, then a hot wire ignition (HWI) test to IEC 60695-2-12 can be carried out on the non-metallic material, of minimum thickness, to determine if there is a risk of fire.

Conformity with 6.8.1 and 6.8.2 is checked by inspection and by evaluation of the data provided by the manufacturer. In the case where no data is provided, conformity is determined by flammability tests.

6.9 Fire enclosures and flame barriers

6.9.1 General

The risk of fire in primary circuits and circuits exceeding ELV limits shall be considered to be reduced to a tolerable level if such circuits of the equipment, and the equipment case, comply with the constructional requirements of 6.9.

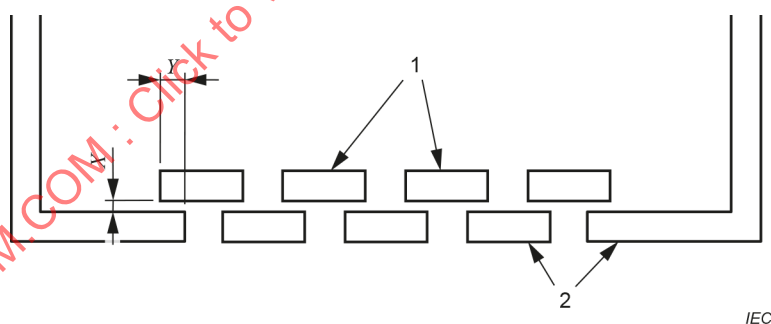
6.9.2 Fire enclosures and flame barrier requirements

The fire enclosure shall meet the following requirements.

- The bottom shall have no openings or, to the extent in Figure 3, shall be constructed with baffles as specified in Figure 2 or be made of metal, perforated as specified in Table 7 or be a metal screen with a mesh not exceeding 2 mm × 2 mm centre to centre and a wire diameter of at least 0,45 mm.
- The equipment case, and any baffle or flame barrier, shall be made of metal (except magnesium) or of non-metallic materials having a flammability class of V-1, or better, of IEC 60695-11-10.
- The equipment case, and any baffle or flame barrier, shall have adequate mechanical strength to protect against electric shock in accordance with Clause 4.

A flame barrier and the bottom of a fire enclosure are considered to comply without test, if in the smallest thickness used, the material is of flammability class V-1 of IEC 60695-11-10 or better.

Conformity with 6.9 is checked by inspection. In case of doubt the flammability class of V-1, or better, is checked on three samples according to IEC 60695-11-10.

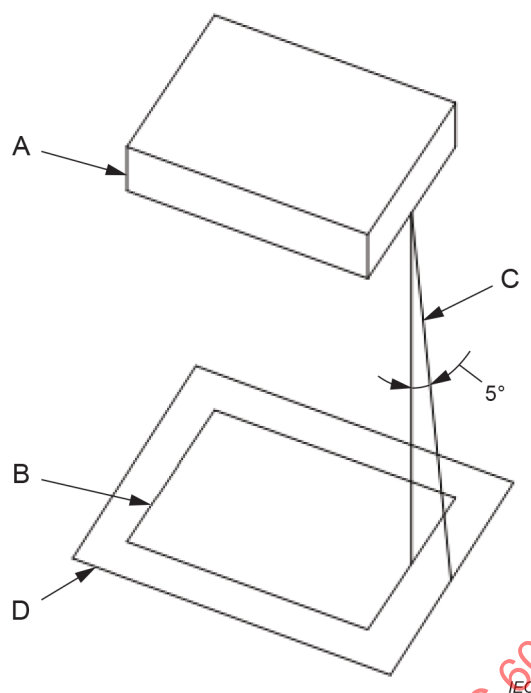


$Y = 2X$ but never less than 25 mm

Key

- 1 Baffle plates (may be below the bottom of the enclosure)
- 2 Bottom of enclosure

Figure 2 – Baffle



Key

- A Part or component of the equipment that is considered to be a source of fire hazard. This consists of an entire component or part of the equipment if it is not otherwise shielded, or the unshielded portion of a component that is partially shielded by its casing.
- B Projection of the outline of A on the horizontal plane.
- C Inclined line that traces out the minimum area of the bottom and sides to be constructed as specified in 6.9. This line projects at a 5° angle from the vertical at every point around the perimeter of A and is oriented so as to trace out the maximum area.
- D Minimum area of the bottom to be constructed as specified in 6.9.

Figure 3 – Location and extent of a flame barrier

Table 7 – Acceptable perforation in the bottom of an equipment case

Minimum thickness mm	Maximum dimension of holes ^a mm	Minimum spacing of holes centre to centre mm
0,76	1,15	1,70
0,76	1,19	2,36
0,81	1,91	3,18
0,89	1,90	3,18
0,91	1,60	2,77
0,91	1,98	3,18
1,00	1,60	2,77
1,00	2,00	3,00

^a The diagonal is the maximum dimension for a square hole.

6.10 Assessment of the fire risk due to a single fault condition

6.10.1 Guidelines for maximum acceptable temperatures when subjecting a circuit or component to a single fault condition

Where it is not practical to protect components against overheating, under a single fault condition, the components shall be mounted on materials of flammability class V-1 or better, of IEC 60695-11-10. Additionally, such components shall be separated from material of a class lower than flammability class V-1 by at least 13 mm of air or by a solid barrier of material of flammability class V-1, or better.

The temperatures specified shall be at the hottest point on the surface of a component or material or within it.

Where it is not possible to meet the above criteria for components and/or circuits subject to overheating under fault conditions, these should be effectively shielded or separated to prevent overheating of their surrounding materials and components (see 6.9). Alternatively, the equipment, mounted under normal use should be subjected to the conformity test in 6.10.3.

6.10.2 Temperature of windings under normal use or a single fault condition

If a hazard could be caused by excessive temperature, the temperature of the insulating material of windings shall not exceed the values of Table 8 in normal use or single fault condition. The values in Table 8 are not applicable for short term overloads. If the temperature of a winding is determined using thermocouples, the values in the table are reduced by 10 °C, except in the case of a winding with embedded thermocouples.

Conformity with 6.10.2 is checked by measurement in the normal use and in the applicable single fault condition.

Table 8 – Insulation material of windings

Class of insulation (as defined in IEC 60085)	Normal use °C	Single fault condition °C
Class A	105	150
Class B	130	175
Class E	120	165
Class F	155	190
Class H	180	210

6.10.3 Conformity of equipment with requirements for protection against the spread of fire

Refer to 9.6.5.5 for single fault testing.

Conformity of equipment to 6.10.3 with requirements for protection against the spread of fire is checked, as a safety type test, by placing the equipment on wrapping tissue (wrapping paper of between 12 g/m² and 30 g/m²), covering a softwood surface and covering the equipment with a single layer of cheesecloth (bleached cotton of approximately 40 g/m²). No molten metal, burning insulation, flaming particles, etc., shall fall on the surface on which the equipment stands, and there shall be no charring, glowing, or flaming of the tissue paper or cheesecloth. Melting of insulation material which is not of importance to the requirements of this document shall be ignored.

6.11 Limited-energy circuit

A limited-energy circuit is a circuit that meets all the following criteria.

- a) The potential appearing in the circuit is not more than 30 V AC RMS or 60 V DC.
- b) The current that can appear in the circuit is limited by one of the following means:
 - 1) the maximum available current is limited inherently or by impedance so that it cannot exceed the relevant value of Table 9;
 - 2) current is limited by an overcurrent protective device according to Table 10;
 - 3) a regulating network limits the maximum available current so that it cannot exceed the relevant value of Table 9 under normal use or as a result of one fault in the regulating network.
- c) It is separated by at least basic insulation from other circuits that would result in energy values exceeding criteria a) and b) above.

If an overcurrent protective device is used, it shall be a fuse or a non-adjustable non-self-resetting electromechanical device.

Conformity to 6.11 is checked by inspection and by measuring the potentials appearing in the circuit, the maximum available current, under the following conditions.

- The potentials appearing in the circuit are measured in the load condition that maximizes the voltage.
- Output current is measured after 60 s of operation, with the resistive load (including short circuit) which produces the highest value of current.

Table 9 – Limits of maximum available current

Open-circuit output voltage, U V			Maximum available current A
AC RMS	DC	Peak ^a	
≤ 20	≤ 20	$\leq 28,3$	8
$20 < U \leq 30$	$20 < U \leq 30$	$28,3 < U \leq 42,4$	8
–	$30 < U \leq 60$	–	$150/U$

^a The peak value applies to non-sinusoidal AC and to DC with ripple exceeding 10 %.

Table 10 – Overcurrent protective device

Potential appearing in the circuit, U V			Current that the protection device breaks after not more than 120 s ^b A
AC RMS	DC	Peak ^a	
≤ 20	≤ 20	$\leq 28,3$	10
$20 < U \leq 30$	$20 < U \leq 60$	$28,3 < U \leq 42,4$	$200/U$

^a The peak value applies to non-sinusoidal AC and to DC with ripple exceeding 10 %.

^b The evaluation should be based on the specified time-current breaking characteristics of the protection device (which is different from the rated breaking current). (For example, in IEC 60127-1, a 4 A, T-type fuse is specified to break at 8,4 A or less at 120 s.) The breaking current of fuses is dependent on temperature and this should be taken into account if the ambient temperature of a fuse is significantly higher than the room ambient temperature.

7 General and fundamental design requirements for safety

7.1 Climatic conditions for safety

Climatic conditions of equipment denote the conditions in the immediate environment.

The equipment safety shall not be impaired by the environmental ranges declared by the manufacturer. These conditions include:

- temperature, operation and storage;
- humidity, non-condensing;
- atmospheric pressure.

7.2 Electrical connections

The design of electrical terminations and connection points shall be such that the expected reliability will be maintained throughout the life of the equipment. Allowance shall be made for the conditions normally encountered in service, for example, corrosion due to humidity, shocks, heat and creep.

Conformity of protective bonding with 7.2 shall be verified by test.

Wires and cables shall be in accordance with the relevant IEC standards.

Conductors and their cross-sections shall comply with the electrical, mechanical and climatic requirements of this document. Furthermore, the structure of the conductors and their cross-sections shall be matched to the connection method used. For example, connection method without screws or soldering shall be in accordance with IEC 60352-1 or IEC 60352-2.

Current-carrying parts shall have the necessary mechanical strength and current-carrying capacity for their intended use. Current transformer primary windings should be restrained mechanically to ensure circuit continuity is maintained during thermal withstand conditions.

For electrical connections, no contact pressure shall be transmitted through insulating material other than ceramic or other material with characteristics no less suitable, unless there is sufficient resilience in the metallic parts to compensate for any possible shrinkage or yielding of the insulation material.

7.3 Components

7.3.1 General

Refer to Annex D for safety-related guidance on the design and application of components for use in equipment within the scope of this document.

7.3.2 High-integrity part or component

Where short-circuiting or disconnection of a component in a single-fault condition could result in a hazard, high-integrity components shall be used.

High-integrity parts and components are regarded as fault-free in relation to the requirements of this document and are not subject to testing in single-fault conditions.

NOTE In addition to the requirements of this document, high-integrity parts and components are constructed, dimensioned and tested according to IEC publications (where applicable) so that their safety and reliability for the expected application is assured.

A single electronic device which employs electron conduction in a vacuum, gas or semiconductor is not regarded as a high-integrity part.

Conformity with 7.3 is checked by inspection of component manufacturers data or by performing the relevant tests.

7.4 Connection to other equipment

Where equipment is intended to be electrically connected to another product, to an accessory, or to a wired network port, interconnection circuits shall be selected to provide continued performance to the requirements of Table A.1. This is normally achieved by connecting ELV circuits to ELV circuits, SELV circuits to SELV circuits, PELV circuits to PELV circuits, PEB circuits to PEB circuits and TNV circuits to TNV circuits. For definitions and information on TNV circuits, refer to IEC 62151. Interconnecting cables can carry more than one type of circuit (SELV circuit, TNV circuit, ELV circuit, hazardous voltage circuit, etc.) provided that they are separated as required by this document. It is possible that HLV circuits be connected to other HLV circuits of other equipment which have compatible electrical ratings.

Conformity with 7.4 is checked by inspection.

Where additional products are specifically complementary to the host (first) equipment (for example, a separate control interface for the equipment), ELV circuits are permitted as interconnection circuits between these items, provided that these continue to meet the requirements of this document when connected together.

7.5 High-intensity light sources

Equipment using high-intensity light sources – for example, fibre optic interfaces – shall be designed in accordance with IEC 60825-1.

7.6 Explosion

7.6.1 General

For information on components not covered by 7.6, see 7.3 and Annex D.

7.6.2 Components at risk of explosion

7.6.2.1 General

When components liable to explode if overheated or overcharged are not provided with a pressure-release device, protection for the user shall be incorporated in the equipment (see 4.10.4.5).

Pressure-release devices shall be located such that a discharge will not cause a hazard to the user. The construction shall be such that any pressure-release device is not obstructed.

7.6.2.2 Batteries

Batteries shall not cause explosion or produce a fire hazard as a result of excessive charge or discharge or if installed with incorrect polarity. Where necessary, protection shall be incorporated in the equipment, unless the manufacturer's instructions specify that it is for use only with batteries which have built-in protection. See Annex F for examples of battery protection circuits.

If an explosion or fire hazard could occur through fitting a battery of the wrong type (for example, where a battery with built-in protection is specified), there shall be a warning marking (see 8.1.10) on or near the battery compartment or mounting and a warning in the manufacturer's instructions. An acceptable marking is symbol 14 of Table 12 (refer to documentation from the manufacturer).

If the equipment has means for charging rechargeable batteries, and if non-rechargeable cells could be fitted and connected in the battery compartment, there shall be a warning marking in or near the compartment (see 8.1.8 and 8.1.10).

The battery compartment shall be designed so that there is no possibility of explosion or fire caused by build-up of flammable gases. Batteries shall be so mounted that safety cannot be impaired by leakage of their electrolyte.

For batteries intended to be replaced by the user, if an attempt is made to install a battery with its polarity reversed, no hazard shall arise.

Conformity is checked by inspection, including inspection of battery data, to establish that failure of a single component cannot lead to an explosion or fire hazard. If necessary, a short circuit and an open circuit are made on any single component (except the battery itself) whose failure could lead to such a hazard.

8 Marking, documentation and packaging

8.1 Marking

8.1.1 General

When mounted in its normal operating position, the equipment should carry, where possible, markings in accordance with 8.1.2 to 8.1.11 inclusive. These markings shall, where possible, be visible from the exterior of the equipment or be visible by removing a cover or the opening of an aperture without the aid of a tool, if the cover or aperture is intended to be removed by the user.

Where, because of space limitations, it is not possible for these markings to be visible in the normal operating position or they are found elsewhere on the equipment, an explanation of these symbols shall be included in the documentation (see Table 12 for the description of the symbols).

Where a hazard exists, the caution symbol 14 of Table 12 and associated hazard symbol shall be displayed as close as possible to the hazard, for example caution symbol and high voltage symbol placed on terminal block. If general warnings are needed, the caution symbol 14 of Table 12 shall be used and the meaning of this shall be detailed in the documentation.

For rack or panel equipment, markings are permitted to be on any surface that becomes visible after removal of the equipment from the rack or panel.

Markings that apply to the whole equipment shall not be placed on parts that can be removed by the user without the use of a tool.

The values of preferred voltages, currents, frequency and their tolerances should be as specified in IEC 60255-1.

The markings listed in Clause 8 shall be considered to be safety-related.

8.1.2 Identification

The equipment shall, as a minimum, be marked with:

- the name or trademark of the manufacturer or supplier;
- the model or type reference;
- if equipment bearing the same distinctive designation (model number) is manufactured at more than one location, the manufacturing location (factory location can be in code).

If the equipment consists of two parts, the part accessible under normal use shall be marked with type and manufacturer. The other part should have all markings in accordance with 8.1.

Conformity with 8.1 shall be checked by inspection.

8.1.3 Auxiliary supplies, measurands, inputs and outputs

8.1.3.1 General requirements for marking

For marking, the following shall be taken into account:

- AC – with symbol 2 of Table 12 and rated frequency or frequency range;
- DC – with symbol 1 of Table 12;
- symbol 3 of Table 12 on equipment for AC and DC supply;
- symbol 4 of Table 12 on equipment for 3 phase AC supply;
- a hyphen (-) shall be used to separate the lower and upper rated voltages and measurands, for example, 125 V-230 V;
- for selectable voltage or current markings:
 - the lower and upper selectable values shall be separated by means of a solidus, forward slash (/), for example, 125 V/230 V, 1 A/5 A;
 - when equipment uses voltages or frequencies where switching is automatic then the markings shall be according to symbol 15 of Table 12 or the word "AUTO" (see the examples in Table 12);
 - where an operating voltage is achieved using an external, separate device, for example, an additional series resistor, then the equipment shall be marked with this operating voltage followed by the legend +EXT.R. (in capital letters), for example, 125 V+EXT.R;
- the burden in watts (active power) or volt-amperes (apparent power) or the rated input current, with all accessories or plug-in modules connected;
- the documentation shall specify the burden of individual digital inputs, output relays and other I/O ports of significant burden in order for the user to calculate the worst-case burden for the equipment application;
- the values shall be measured with the equipment powered at rated voltage, but without being operational; the measured value shall not exceed the marked value by more than 10 %;
- the rated supply voltage(s) or the rated supply voltage range.

If the equipment can be used on more than one voltage range then the separate voltage ranges shall be marked unless their maximum and minimum values do not differ by more than 20 % of the mean value.

If a user can set different rated supply voltages on the equipment then a means of indication for the set voltage shall be provided on the equipment. If AC or DC supply setting alteration can be achieved without the use of a tool, then the action of changing the setting shall also change the indication.

8.1.3.2 Auxiliary supply

The following information shall be provided:

- on the equipment and in the documentation:
 - AC and/or DC supply;
 - the rated values;
- in the documentation:
 - the burden;
 - the operating voltage range (in accordance with IEC 60255-1).

8.1.3.3 Measurands

The following information shall be provided:

- on the equipment and in the documentation:
 - the rated values, for example, voltage, current, frequency;
- in the documentation:
 - the burden;
 - the operating voltage range (in accordance with IEC 60255-1);
 - the overload withstand.

8.1.3.4 Inputs

The following information shall be provided:

- in the documentation:
 - AC and/or DC supply;
 - the rated values;
 - the burden.

NOTE For optical LPIT the rated values are the rated primary current for the optical LPIT input.

8.1.3.5 Outputs

The following information shall be provided:

- in the documentation:
 - the kind of output type, for example, normally open contact, change-over contact, etc;
 - the contact performance in accordance with IEC 60255-1.

Conformity with 8.1.3.1 to 8.1.3.5 is checked by inspection or by measurement.

8.1.4 Fuses

Where a replaceable equipment fuse is used, the fuse rating and type (for example, the indication of rupturing speed) shall be marked adjacent to the fuse and details provided in the user manual. If the fuse is soldered into the printed circuit board, or there is not sufficient space on the board, then fusing details shall be provided in the user manual only.

Rupturing speed codes of IEC 60127-1 shall be used; see Table 11.

Table 11 – Fuse types

Fuse type	Identification
very quick-acting	FF or black
quick-acting	F or red
medium time lag	M or yellow
time lag	T or blue
long time lag	TT or grey

The recommended ratings of protective fuses or other external protective devices necessary to ensure that the equipment is safe under single fault conditions shall be detailed in the equipment installation and technical documentation.

Conformity with 8.1.4 shall be checked by inspection.

8.1.5 Measuring circuit terminals

Marking shall be adjacent to the measuring terminals. Where there is insufficient space (as in multi-port equipment), it is permissible for the marking to be on the rating plate or for the terminal to be marked with symbol 14 of Table 12.

Where space permits, voltage and current terminals of measuring circuits shall be marked with the rated maximum working voltage or current as applicable, otherwise symbol 14 of Table 12 shall be used.

If there is a direct risk of electric shock due to accidental contact, for example terminal access does not comply with protective type IP2X (or better) according to 5.1 of IEC 60529:1989, then symbol 14 and/or 12 of Table 12 shall be used.

A permitted exception is where circuit terminals are dedicated to specific terminals of other equipment, which are provided with a means of identity. An example is a measuring circuit interconnection between two protective devices.

Conformity with 8.1.5 shall be checked by inspection.

8.1.6 Terminals and operating devices

Where necessary for safety, an indication using words, numbers or symbols shall be given of the purpose of all terminals, connectors, controls and indicators, including any operating sequences. Where there is insufficient space, it is permissible to use symbol 14 of Table 12. In such cases, the relevant information shall be provided in the equipment documentation.

AC or DC supply input connection terminals shall be identifiable.

Other markings of terminals and control devices should be adjacent to or on the terminal, but preferably not on any part which can be removed without the aid of a tool. The markings apply to the following:

- functional earth terminals with symbol 5 of Table 12;
- protective conductor terminals with symbol 6 of Table 12.

If the protective conductor terminal is part of a component (for example, terminal block) or subassembly and there is insufficient space, then it should be marked with symbol 5 of Table 12.

Marking should not be indicated on easily changeable fixtures such as screws. Where the power and earth connections are provided by a plug or socket device, there is no requirement to mark the earth connection adjacent to such a device.

Circuit terminals designed to be accessible, floating at a voltage which is not hazardous live, are permitted to be connected to a common functional earth terminal or system (for example, a co-axial screening system). This terminal shall be marked with symbol 7 of Table 12, if this connection is not self-evident.

If the equipment contains high-intensity light sources of class 2 rating or higher, and the output of these can be viewed under normal use or maintenance use, then the equipment shall be marked with symbol 16 of Table 12.

Conformity with 8.1.6 shall be checked by inspection.

8.1.7 Equipment protected by double or reinforced insulation

Equipment protected throughout by double or reinforced insulation shall be marked with symbol 11 of Table 12, unless this equipment is provided with a protective conductor terminal or if a functional earth connection (for example, via cable screen) can be made to the equipment, under normal use.

Equipment which is only partially protected by double or reinforced insulation shall not bear symbol 11 of Table 12.

Conformity with 8.1.7 shall be checked by inspection.

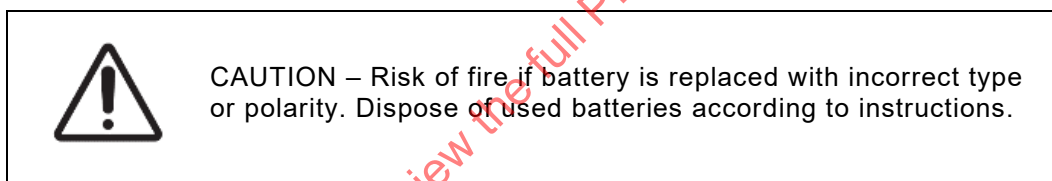
8.1.8 Batteries

8.1.8.1 Replaceable batteries

If the equipment has replaceable batteries and the replacement of these by an incorrect type of battery could result in an explosion (for example, in the case of certain types of lithium batteries) then:

- if a user can access the battery, there shall be a marking close to the battery or a statement in both the operating instructions and commissioning maintenance instructions;
- if the battery is elsewhere in the equipment, marking is required; this shall be close to the battery or in a statement included in the commissioning maintenance instructions.

The marking or statement shall be similar to the following.



It is permissible, where space is limited on the equipment, to use symbol 14 of Table 12.

The polarity of the battery shall be marked on the equipment unless it is not possible to insert the battery with incorrect polarity.

8.1.8.2 Charging

Equipment which has facilities for the recharging of batteries where non-rechargeable cells could be fitted and connected in the battery compartment shall be marked in or near to this compartment, warning against the charging of non-rechargeable batteries. This warning shall also indicate the type of rechargeable battery that shall be used within the recharging circuit.

Where space does not permit, this information shall be provided in the equipment documentation. In such cases, it is preferred that symbol 14 of Table 12 be adjacent to the battery.

Conformity with 8.1.8.1 and 8.1.8.2 is checked by inspection.

Table 12 – Symbols

Number	Symbol ^b	Symbol reference	Description
1		IEC 60417-5031:2002-10	Direct current
2		IEC 60417-5032:2002-10	Alternating current
3		IEC 60417-5033:2002-10	Both direct and alternating current
4		IEC 60417-5032-1:2002-10	Three-phase alternating current
5		IEC 60417-5017:2006-08	Earth; ground
6		IEC 60417-5019:2006-08	Protective earth; protective ground
7		IEC 60417-5020:2002-10	Frame or chassis
8		IEC 60417-5021:2002-10	Equipotentiality
9A		IEC 60417-5007:2002-10	On (Power)
9B		IEC 60417-5008:2002-10	Off (Power)
10		IEC 60417-5010: 2002-10	On or Off (push-push)
11		IEC 60417-5172:2003-02	Protective Class II equipment
12 ^a		IEC 60417-6042:2010-11	Caution, risk of electric shock
13 ^a		IEC 60417-5041:2002-10	Caution, hot surface
14 ^a		ISO 7000-0434B:2004-01	Caution ^c
15		ISO 7000-0017:2004-01	Automatic control (Closed loop)
16		IEC 60417-5152:2002-10	Radiation of laser apparatus

^a Colour requirements for symbols 12, 13 and 14 do not apply to markings on equipment provided that the symbol is moulded or engraved to a depth or raised height of 0,5 mm or that the symbol and outline are contrasting in colour with the background.

^b Warning symbol dimensions should be as specified in IEC 60417.

^c Caution symbol is a general warning and means refer to documentation for full details of hazard.

8.1.9 Test voltage marking

The symbols indicated in Table 13 shall be used for marking of the test voltage(s) if the manufacturer chooses to mark the equipment.

Table 13 – Symbols for marking of test voltage(s)

Number	Symbol	Publication	Description
1		IEC 60417-5179:2002-10	Test voltage (Dielectric), 500 V
2		IEC 60417-5179:2002-10 modified to show higher dielectric voltage	Test voltage (Dielectric) above 500 V (Example shown 2 kV)
3		IEC 60417-5179-1:2009-08	Test voltage impulse, 1 kV
4		IEC 60417-5179-1:2009-08 modified to show higher impulse voltage	Test voltage impulse above 1 kV (Example shown 5 kV)

8.1.10 Warning markings

In general, for rack-mounted or panel-mounted equipment, markings are permitted on any surface that becomes visible after removal of the equipment from the rack or panel. Markings should not be on the bottom of the equipment, except on hand-held equipment or where space is limited.

This is also applicable to the rear plate of rack-mounted or panel-mounted equipment where there is insufficient space for warning markings. Symbols 14 and/or 12 of Table 12 shall be used in this case, as close as possible to the rear plate.

Where access in normal use presents a risk of electric shock, the warning marking symbol 12 of Table 12 shall be used; this shall be visible either from the front panel or be visible after removing a cover or opening a door or flap without the aid of a tool.

If the user needs to refer to equipment documentation or instruction literature, then the equipment shall be marked with symbol 14 of Table 12.

The equipment documentation shall state that the equipment shall be isolated or disconnected from hazardous live voltage before access to potentially hazardous-live-parts is affected.

Equipment having batteries shall be marked according to the requirements of 8.1.8.

The size of warning markings shall be as follows.

- Symbols shall be at least 2,75 mm high. Text shall be at least 1,5 mm high and contrast in colour with the background.
- Symbols or text moulded, stamped or engraved in a material shall be at least 2,0 mm high. If not contrasting in colour, they shall have a depth or raised height of at least 0,5 mm.

Conformity with 8.1.9 and 8.1.10 shall be checked by inspection and measurement.

8.1.11 Marking durability

All markings shall remain clear and legible under conditions of normal use and shall resist the effects of cleaning agents as specified by the manufacturer. This shall also include the effect of natural or artificial light.

An adhesive that is permanent shall be used to secure adhesive labels

Conformity shall be checked by performing the following test for durability of markings on the outside of the equipment. The markings are rubbed by hand, without undue pressure, for 30 s with a cloth soaked with each specified cleaning agent (or, if not specified, with 70 % isopropyl alcohol).

After the above treatment, the markings shall be clearly legible and adhesive labels shall not have worked loose or become curled at the edges.

8.2 Documentation

8.2.1 General

The equipment documentation shall follow the documentation guideline in IEC 60255-1. The manufacturer shall supply, on request, documentation relating to equipment type tests and routine testing. The product safety instructions shall be included with the equipment in paper format. All other information may be supplied in electronic format. Where applicable, warning statements and a clear explanation of warning symbols marked on the equipment shall be included in the documentation. In particular, wherever symbol 14 of Table 12 is used, there shall be a statement to the effect that the documentation shall be consulted to establish the nature of any potential hazard and any actions which need to be taken to eliminate or minimize this hazard.

The documentation shall include the following:

- a statement that the integrity of any protective conductor connections shall be checked before carrying out any other actions;
- a statement that the equipment ratings, operating instructions and installation instructions shall be checked before commissioning or maintenance use;
- the information specified in 8.2.2 to 8.2.5;
- the intended use of the equipment.

8.2.2 Equipment ratings

8.2.2.1 General

The equipment documentation shall include the following:

- the installation category (overvoltage category) for which the equipment is intended (this is related to the ability of the equipment to withstand transient overvoltages);
- the supply voltage or voltage range, frequency or frequency range and power or current rating of the equipment;
- the permitted fluctuation from the rated functional value, for example, the lower and upper values of the voltage range;
- a description of all input and output connections.

8.2.2.2 Fuses and external protective devices

The type, current rating and voltage rating of any internal fuse shall be stated according to 8.1.4. This shall include fuses that can or cannot be accessed by a user for replacement.

The recommended fuse type or other protective means shall take into account the switching capacity and interrupting speed.

The type, current rating and voltage rating of any external fuse or protective device required for safe operation of the equipment shall be given in the product documentation.

Where it is recommended that an external switch, circuit breaker or other protective device be connected near to the equipment, this shall be stated.

8.2.2.3 Environmental requirement

The equipment documentation shall state the following:

- the operating ambient temperature range;
- the maximum altitude it is designed to operate up to;
- the IP rating at the front of the equipment when it is mounted in its normal position of use;
- the impact test IK rating;
- the pollution degree for the equipment – for example, pollution degree 2 – when mounted in its normal position of use;
- the insulation class of the equipment – for example, Class I equipment – when mounted in its normal position of use.

Conformity with 8.2.1 to 8.2.2.3 is checked by inspection.

8.2.3 Equipment installation

For installation purposes, the equipment documentation shall include the following, as appropriate.

- Instructions relating to the safe mounting of the equipment shall be stated including any specific location and assembly requirements.
- Instructions relating to the protective earthing of the equipment shall be stated. This shall include a recommendation of the size of wire to be used and a statement indicating that protective earth connections shall not be removed when the equipment is energized.
- Any special ventilation requirements shall be stated. This is related to the heat dissipated by the equipment.
- The manufacturer shall also indicate the maximum number or percentage of digital input circuits and output relays, which can be energized simultaneously at the maximum ambient temperature.
- Wire type, size and rating necessary for correct installation and safety of the equipment shall be indicated.
- Information regarding the requirement for and the specification of any external devices required for the safe operation of the equipment, as in 8.2.2.2 shall be included.

Conformity with 8.2.3 is checked by inspection.

8.2.4 Equipment commissioning and maintenance

Equipment instructions concerning preventative maintenance and inspection shall be given in enough detail to ensure the safety of these procedures. Instructions shall include recommendations relating to safety earthing and de-energization of the equipment, where applicable.

The following shall also be included, where applicable.

- Instructions for fault-finding and repair, where applicable, shall be given to the extent that is relevant for operation and maintenance use.
- The manufacturer shall specify any parts, which shall only be examined or supplied by the manufacturer or the manufacturer's agent.
- The manufacturer shall specify the safe methods for changing and disposal of:
 - any accessible fuses including type and ratings as per 8.1.4;
 - any replaceable batteries, for example, lithium, and/or suitable replacements where applicable;
 - the method of safe recharging and/or replacement for rechargeable batteries with recommendation of suitable replacements where applicable;
 - where high-intensity light sources are fitted, warnings shall be given that these should not be viewed directly.

Conformity with 8.2.4 is checked by inspection.

8.2.5 Equipment operation

Operating instructions for the equipment shall include the following

- A requirement that before working on CT circuits, these shall be short-circuited.
- A statement indicating that it is the responsibility of the user to ensure that the equipment is installed, operated and used for its intended function in the manner specified by the manufacturer. Also that, if this is not the case, then any safety protection provided by the equipment can be impaired.
- An explanation of, and where possible pictures of, symbols used on the equipment according to 8.1.

8.3 Packaging

The scope of this document does not cover the transportation of equipment between the manufacturer and the customer. However, the manufacturer shall ensure that the equipment is suitably packaged and labelled to withstand, without damage, reasonable handling and environmental conditions appropriate to the method(s) of transportation to the customer's delivery address.

9 Type tests and routine tests

9.1 General

Equipment shall be designed to meet the requirements of all relevant clauses of this document and tested to prove conformity where necessary. Type testing alone (as Table 14 type tests) does not form a complete safety assessment and does not guarantee that the correct components and materials have been used; this can only be achieved by assessment against all clauses of this document.

Table 14 – Overview of tests

Test	Reference	Type tests ^{a,g} Safety (normative)	Routine test ^g
Environmental tests			
Dry-heat test – operational	9.6.1.2	X ^{c,e}	—
Cold test – operational	9.6.1.3	X ^{c,e}	—
Dry-heat test at maximum storage temperature	9.6.1.4	X ^e	—
Cold test at minimum storage temperature	9.6.1.5	X ^e	—
Damp-heat, steady state test	9.6.1.6	X ^{d,e}	—
Damp-heat, Cyclic	9.6.1.7	X ^{d,e}	—
Vibration	9.6.2.1	X ^f	—
Shock	9.6.2.2	X ^f	—
Bump	9.6.2.3	X ^f	—
Seismic	9.6.2.4	X ^f	—
Safety-related tests			
Leakage current	4.7	X	—
Clearances and creepage distances	9.6.3	X	—
Accessible parts test	9.6.2.5	X	—
IP rating	9.6.2.6	X	—
Impulse voltage	9.6.4.2	X	—
AC or DC dielectric voltage	9.6.4.3	X	X
Insulation resistance	9.6.4.4	X	—
Protective bonding resistance	9.6.4.5.1	X	—
Protective bonding continuity	9.6.4.5.2	---	X
Flammability of insulating materials, components and fire enclosures ^c	9.6.5.2	X ^b	—
Single fault condition	9.6.5.5	X	—
Reverse polarity and slow ramp	9.6.6	X	—
Resistance to mechanical stress	9.6.7	X	—
Marking durability	8.1.11	X	—
Electrical environment tests			
Maximum temperature of parts and materials	9.6.5.1	X	—
Thermal short time	9.6.5.3	X	—
Output relay, make and carry	9.6.5.4	X	—
^a Conformity with type-test requirements may be carried out by testing, measurement, visual inspection or assessment, as appropriate. For example, clearance and creepage distance measurement (or visual inspection where the distances are obviously large) or technical argument such as assessment of single fault conditions where the result would be known. There shall be no electrical shock or fire hazard during or after conducting the normally applied type tests to demonstrate claimed conformity. ^b Testing of plastic parts may be necessary where the material does not meet the minimum flammability specified in Clause 6, or its thickness is below the minimum specified for that material to achieve the required minimum flammability. ^c The safety critical components shall be checked to ensure they remain within their operating temperature. This can be measured during the temperature tests or can be measured at room temperature and extrapolated. ^d Safety critical components shall be checked to ensure that insulation properties are maintained (this can be via testing of individual component or checking of manufacturer's data). ^e Upon completion of the tests the solid insulation shall be tested by application of the AC or DC dielectric voltage and insulation resistance test to prove it has not been compromised. ^f Upon completion of the tests the AC or DC dielectric voltage test and the impulse voltage test shall be carried out to prove that there is no degradation. ^g X: applicable; —: not applicable			

Single fault testing shall be carried out unless it can be demonstrated that it is improbable that a hazard can arise from a single fault condition (see 4.10).

9.2 Safety type tests

Safety type tests are normative and carried out to verify that the equipment complies with the safety requirements of this document. Unless otherwise specified, safety type tests may be carried out in any appropriate sequence. A safety type test may be carried out on a pre-production sample or on different samples of the same type.

Unless otherwise agreed, safety type tests shall be performed on all equipment which has not previously been the subject of satisfactory safety type testing or which has been the subject of modifications which could affect the performance of the equipment.

Where certain details of the equipment are altered, the safety type test(s) whose results could be affected by the alterations shall be repeated.

The safety type test may be carried out by the manufacturer or an independent test house. The manufacturer shall provide the customer with access to documentary evidence of satisfactory results when required to do so.

Type testing a product which is part of a product family shall be considered sufficient to cover the entire product family provided a documented risk assessment is carried out to determine which type tests are valid and which tests need to be repeated on the rest of the product family.

An example risk assessment process is given in Annex G.

9.3 Routine testing

A conformity test shall be conducted on each individual item during or after manufacture to confirm that the equipment's design features for protection against electric shock have not been compromised. Unless otherwise specified, these tests may be carried out in any sequence. See 9.6.4.3.2 for further detail on routine testing.

9.4 Conditions for testing

The type tests shall be performed under the test reference conditions given in IEC 60255-1.

The following data for each test to be conducted shall be accessible from the manufacturer on request:

- the cross-sectional area and length of connecting cables, if these can affect the type test results for example, temperature rise;
- for vibration testing, details of cable terminations and looming, including the position of wire loom supports;
- measurement accuracy and tolerance permitted for all measurements.

Where applicable, the data shall include:

- initial measurement;
- measurement during the individual test;
- final measurement.

9.5 Verification procedure

The verification procedure shall ensure that the equipment is in accordance with its specification and that it functions correctly during the initial measurement at the beginning of the test

sequence and maintains its design characteristics throughout all the following individual tests where this has been specified.

The order for testing is initial measurement, measurement during the individual test and final measurement.

The exception to this is after single fault condition testing where the only verification required is that the equipment does not pose a fire or electric shock hazard and that the dielectric withstand has not been compromised.

In a test sequence where the final measurement of the previous test corresponds to the initial measurement of the succeeding individual test, it is not necessary to do these measurements twice, once is sufficient.

The above measurements comprise a visual inspection and a functional test to ensure that the equipment is in accordance with its specification.

9.6 Tests

9.6.1 Climatic environmental tests

9.6.1.1 General

The purpose of the climatic environmental tests is to ensure the insulation and components are operating within their temperature range without degradation. The solid insulation is tested by the application of the AC or DC dielectric voltage test and impulse test.

9.6.1.2 Dry-heat test – operational

The dry-heat operational test shall be performed in accordance with IEC 60255-1 to prove the resistance of the equipment to heat, whilst operational.

9.6.1.3 Cold test – operational

The operational cold test shall be performed in accordance with IEC 60255-1 to prove the resistance of the equipment to cold, whilst operational.

9.6.1.4 Dry-heat test at maximum storage temperature

The dry-heat storage test shall be performed in accordance with IEC 60255-1 to prove the resistance of the equipment to storage heat.

9.6.1.5 Cold test at minimum storage temperature

The cold storage test shall be performed in accordance with IEC 60255-1 to prove the resistance of the equipment to cold storage.

9.6.1.6 Damp-heat, steady state test

To prove the resistance to humidity, the equipment shall be subjected to a damp-heat, steady state test in accordance with IEC 60255-1. The requirements of the test are also regarded as fulfilled if the equipment is composed of sub-assemblies, components and parts which have already passed this test in a comparable test combination. If necessary, a test of those sub-assemblies which have not yet been tested is sufficient.

9.6.1.7 Damp-heat, cyclic

To prove the resistance to cyclic damp-heat, the equipment shall be subjected to a cyclic temperature with humidity test in accordance with IEC 60255-1.

9.6.2 Mechanical tests

9.6.2.1 Vibration

To prove the robustness of the hardware design the equipment shall be subjected to vibration response and vibration endurance testing in accordance with IEC 60255-1 and shall be verified by the application of the AC or DC dielectric voltage test and the impulse voltage test.

9.6.2.2 Shock

To prove the robustness of the hardware design the equipment shall be subjected to shock response and shock withstand testing in accordance with IEC 60255-1 and shall be verified by the application of the AC or DC dielectric voltage test and the impulse voltage test.

9.6.2.3 Bump

To prove the robustness of the hardware design the equipment shall be subjected to bump testing in accordance with IEC 60255-1 and shall be verified by the application of the AC or DC dielectric voltage test and the impulse voltage test.

9.6.2.4 Seismic

To prove the robustness of the hardware design the equipment shall be subjected to seismic testing in accordance with IEC 60255-1 and shall be verified by the application of the AC or DC dielectric voltage test and the impulse voltage test.

9.6.2.5 Accessible parts test

The purpose of this test is to verify that equipment cases, barriers or mounting panels prevent hazardous-live-parts being accessible in normal use.

This test, according to 4.3.3.2, shall be carried out as a type test for the equipment to verify that hazardous-live-parts cannot be accessed and that the voltage or energy does not exceed the safe limits for normal use.

9.6.2.6 Degree of protection provided by the enclosure

The ingress protection shall be tested to confirm that the equipment case meets the manufacturer's claimed IP code in normal use. The tests shall be in accordance with those specified in IEC 60529:1989, IEC 60529:1989/AMD1:1999, IEC 60529:1989/AMD2:2013.

9.6.3 Clearances and creepage distances

Unless otherwise determined – for example, from computer assisted design (CAD) data, drawing or inspection – that the required clearance and creepage distances are compliant with the values in the appropriate Annex C table, measurements shall be made. Where the minimum clearance value is not met, then the clearance may be proven by testing (see 4.9.2.2). Testing to prove the clearance in air cannot be used to demonstrate conformity of the associated creepage distance.

Where a transient suppressor is used to reduce the overvoltage, the circuit shall be tested to show that it withstands the surge test in accordance with IEC 60255-26 and that the transient suppression is adequately rated (not damaged).

9.6.4 Safety-related electrical tests

9.6.4.1 General

The purpose of the voltage tests in 9.6.4.2 to 9.6.4.4 is to prove clearances and solid insulation.

The test voltage level shall be the open-circuit voltage of the generator before connection to the equipment.

9.6.4.2 Impulse voltage test

9.6.4.2.1 General

The impulse voltage type test is carried out with a voltage having a 1,2/50 μ s waveform (see IEC 61180) and is intended to simulate overvoltages of atmospheric origin. It also covers overvoltages due to switching of low-voltage equipment.

9.6.4.2.2 Test procedures

The impulse voltage test shall be carried out in accordance with the following.

The impulse voltage shall be applied to the appropriate points accessible from the outside of the equipment; the other circuits and the accessible conductive parts shall be connected together and to earth.

The tests for proving clearances shall be conducted for a minimum of three impulses of each polarity with an interval of at least 1 s between impulses.

The same test procedure also applies for proving the capability of solid insulation; however, five impulses of each polarity shall be applied in this case, and the wave shape of each impulse shall be monitored and failures recorded.

Both tests, for proving clearances and solid insulation, may be combined in one common test procedure.

9.6.4.2.3 Waveform and generator characteristics

A standard impulse voltage in accordance with IEC 61180 shall be used. The parameters are detailed in Table 15.

Table 15 – Impulse generator characteristics

Parameter	Level
open-circuit voltage	see tables in Annex C ± 10 %
front time	1,2 μ s ± 30 %
time to half-value	50 μ s ± 20 %
output impedance	500 Ω ± 10 %
output energy	0,5 J ± 10 %
test lead length	< 2 m

9.6.4.2.4 Selection of impulse test voltage

The applicable rated impulse test voltage shall be at least the appropriate impulse voltage selected from the tables in Annex C. Alternatively the manufacturer can claim a higher level of rated impulse test voltage in which case that higher level shall be used for testing.

When zero-rated impulse test is specified for particular equipment circuits, these shall be exempt from the impulse voltage test.

When the test is between two independent equipment circuits, the higher of the two rated impulse voltages shall be used for the test. Decoupling capacitors can provide a route for the

impulse test voltage and produce an apparent test failure. In that case the test level should be stated in the user documentation.

9.6.4.2.5 Performing of tests

The impulse voltage type test is applicable whether or not the equipment under test is fitted with surge suppression. If surge suppression devices are fitted these shall not be removed for the test.

Unless otherwise specified, the impulse voltage test shall be performed:

- between each circuit and the accessible conductive parts;
- between independent circuits, the terminals of each independent circuit being connected together;
- across the terminals of a given circuit to validate the manufacturer's claim.

Circuits specified for the same rated insulation can be grouped together.

Circuits not involved in the tests shall be connected together and to earth.

Unless obvious, the independent circuits are those which are so described by the manufacturer.

For equipment with an insulated case, the accessible conductive parts shall be represented by a metal foil covering the whole equipment case except the terminals around which a suitable gap shall be left so as to avoid flashover to the terminals. The test between two independent circuits shall be carried out, unless otherwise specified, at the higher impulse voltage specified for the two circuits.

9.6.4.2.6 Test acceptance criteria

There shall be no disruptive discharge (spark-over, flashover or puncture) during test. Partial discharges in clearances which do not result in breakdown are disregarded. After this type test, the equipment shall comply with all relevant performance requirements.

It is permissible for an impulse voltage waveform applied across test points connected to surge suppression, inductive devices or potential dividers, to be attenuated or distorted if this is not due to electrical breakdown.

The waveform applied to test points not connected to such devices, will not be noticeably distorted or attenuated unless the insulation does not withstand the impulse voltage test.

9.6.4.3 AC or DC dielectric voltage test

9.6.4.3.1 Type testing

9.6.4.3.1.1 Performing the dielectric voltage test

Type tests shall be applied:

- between each circuit and the accessible conductive parts, the terminals of each independent circuit being connected together;
- between independent circuits, the terminals of each independent circuit being connected together.

Unless obvious, the independent circuits are those which are so described by the manufacturer. The test voltage for independent circuits shall be the higher requirement of the two independent circuits assessed.

Circuits specified for the same rated insulation voltage may be connected together when being tested to the accessible conductive parts.

If applicable, the manufacturer shall declare the dielectric voltage withstand across open metallic contacts and verify this by type testing.

Circuits with transient suppression devices fitted across contacts shall be either tested using DC (both polarities) or shall have the transient suppression devices removed in order to perform the test. Circuits not involved in the tests shall be connected together and to earth.

The test voltages shall be in accordance with Annex C applied directly to the terminals.

For equipment with an insulating case, the accessible conductive parts shall be represented by a metal foil covering the whole equipment case except the terminals around which a suitable gap shall be left so as to avoid flashover to the terminals. Insulation tests requiring this metal foil shall be performed as type tests only.

9.6.4.3.1.2 Value of the dielectric test voltage

The applicable dielectric withstand voltage shall be at least the appropriate dielectric withstand voltage selected from the tables in Annex C. Alternatively the manufacturer can claim a higher level of dielectric withstand voltage, in which case that higher level shall be used for testing.

For circuits directly energized via instrument transformers or connected to a station battery, the test voltage shall not be less than 2,0 kV AC RMS, 1 min. Where this is not the case, see C.1.3 for the determination of the rated insulation voltage for circuits energized from various supplies.

A higher test voltage of 2,5 kV AC RMS for 1 min for CT circuits may be claimed by the manufacturer. Higher test voltages shall be specified for pilot wire circuits where short-circuit current induced overvoltages on the pilot wires are to be expected. The applicable test voltage shall, in this case, be declared by the manufacturer.

If applicable, the manufacturer shall declare the dielectric voltage withstand for open metallic contacts and verify this by type testing.

9.6.4.3.1.3 Test voltage source

The test voltage source shall be such that, when applying half the specified value to the equipment under test, the voltage drop observed is less than 10 %.

The source voltage value shall be verified with accuracy better than ± 5 %.

The test voltage shall be substantially sinusoidal and at a frequency between 45 Hz and 65 Hz. Certain factors, for example, capacitors to earth for EMC conformity, will lead to increased test current and thus make detection of a breakdown condition difficult. This problem can be overcome by using a DC test voltage ($1,4 \times \text{RMS}$) or by measuring AC resistive current only.

9.6.4.3.1.4 Test method

For type tests the open-circuit voltage of the test generator is applied to the equipment at zero volts. The test voltage shall be raised smoothly to the specified value in such a manner that no appreciable transients occur and shall be maintained for 1 min minimum. It shall then be reduced smoothly to zero as rapidly as possible.

For routine tests, the test voltage may be maintained for 1 s minimum. In this case, the test voltage shall be 10 % higher than the specified 1 min type test voltage.

9.6.4.3.1.5 Test acceptance criteria

During the dielectric voltage test, no breakdown or flashover shall occur. Partial discharges which do not cause the maximum test current level set by the manufacturer to be exceeded, shall be disregarded.

9.6.4.3.1.6 Repetition of the dielectric voltage test

For equipment in a new condition, dielectric voltage tests may be repeated, if necessary, to verify their performance.

9.6.4.3.2 Routine tests

Routine dielectric voltage tests shall be applied:

- between all independent circuits and the accessible conductive parts, the terminals of all independent circuits being connected together;
- between independent circuits, the terminals of all other independent circuits being connected together. If a risk assessment indicates that testing between particular independent circuits is not necessary, then the tests for those circuits may be omitted.

Guidance for routine dielectric voltage testing for safety is provided in Table 16.

Table 16 – Guidance for routine dielectric voltage testing for safety

Risk	Probability	Routine test ^c	
		Assembled board or module	Assembled equipment
Manufacturing and/or design related issues typically due to: • solder bridging between PCB tracks and/or pads; • component leads either not cropped to the specified length or bent in the wrong direction; • component insulation failure; • solder resist or conformal coating badly applied to the PCB; • handling.	Medium	X ^{a,b}	X ^{a,b}
Assembly issues – clearance reduced typically due to errors such as: • conductive component (heat sink, etc.) not correctly fitted; • fixing screw too long; • conductive instead of non-conductive parts used; • extraneous parts such as screws, nuts and wire offcuts.	Low	—	X ^b
^a Routine tests can be carried out on an assembled board and/or module, or on assembled equipment, or on both. ^b All tests are 1 min at rated dielectric test voltage or for 1 s at 110 % rated dielectric test voltage. ^c X: applicable; —: not applicable			

9.6.4.4 Insulation resistance

The insulation resistance measurement shall be performed in conjunction with environmental testing to ensure that the insulation has not been over-stressed and weakened by the applied tests, see Table 14.

The measuring voltage shall be applied directly to the equipment terminals:

- between each circuit and the accessible conductive parts, the terminals of each independent circuit being connected together;

- between independent circuits, the terminals of each independent circuit being connected together.

NOTE Insulation resistance measurement (circuit to ground) is not required for resistor divider arrangements.

The insulation resistance shall be determined when a steady value has been reached and at least 5 s after applying a DC voltage of 500 V $\pm$ 10 %.

The insulation resistance shall not be less than 1 M Ω at 500 V DC. After the damp-heat, steady state type test, the insulation resistance shall not be less than 1 M Ω at 500 V DC, after a recovery time of between 1 h and 2 h, at reference ambient conditions.

9.6.4.5 Protective bonding tests

9.6.4.5.1 Protective bonding resistance – Type test

Accessible conductive parts and terminations connected to the protective conductor for protection against any electric shock hazard shall not have excessive resistance.

For equipment where the protective conductor connection is by means of one core of a multi-cored cable, the cable is not included in the measurement, provided that the cable is supplied by a suitably rated protective device which takes into account the size of the conductor.

The conformity of such parts with protective bonding resistance type test requirements shall be determined using the following test parameters:

- the test current shall be twice that of the maximum current rating of the overcurrent protection means, specified in the user documentation, but not less than 20 A;
- the test voltage shall not exceed 12 V AC RMS or 12 V DC;
- the test duration shall be 60 s;
- the resistance between the protective conductor terminal and the part under test shall not exceed 0,1 Ω .

9.6.4.5.2 Protective bonding continuity – Routine test

Accessible conductive parts which can become live in the event of a single fault condition shall be subject to a low current continuity test to verify their bonding to the protective conductor terminal.

The continuity tester open-circuit voltage and short-circuit current should be chosen to avoid any circuit damage.

9.6.5 Electrical environment and flammability

9.6.5.1 Maximum temperature of parts and materials

The maximum temperature of parts and materials under normal use (see 6.3) and under a single fault condition (see 6.10) may be determined by testing.

9.6.5.2 Flammability of insulating materials, components and fire enclosures

Testing of parts may be necessary where either the material does not meet the minimum flammability requirements specified in 6.6, or its thickness is below the minimum specified for that material to achieve the required minimum flammability.

Tests shall not be required to determine the flammability of insulating materials and components providing they meet the requirements of 6.6.2 to 6.6.4 and fire enclosures 6.9.

9.6.5.3 Thermal short-time test

9.6.5.3.1 Thermal overload

The maximum temperature of the insulating materials, during the following tests, shall be within the limits given for the appropriate insulation class in Table 8.

a) Voltage input:

The equipment voltage input circuits shall withstand overvoltages declared by the manufacturer, without creating any safety hazard, for both continuous and for 10 s overvoltage levels.

b) Current input:

The equipment current input circuits shall withstand continuous and 1 s duration rated overcurrents declared by the manufacturer, without creating any safety hazard or exceeding any component rating. The effectiveness of insulation shall be tested by:

- measuring the temperature of insulating materials to ensure that they stay within their operating range during the tests; or
- performing the dielectric and insulation resistance after tests to ensure the insulation has not been damaged.

However, the manufacturer shall only state safe withstand values.

Safety requirements for protection equipment, with CTs rated between 0,5 A and 5 A are as follows:

- 1) minimum 1 s overcurrent withstand shall be 100 times the rated current;
- 2) continuous withstand shall be at least four times the rated current.

For protection equipment and measuring relays which do not meet these requirements, the manufacturer shall declare the overcurrent withstand and continuous withstand.

9.6.5.3.2 Short time limiting dynamic overload

The purpose of the short time limiting dynamic overload test is to check if a relay withstands the resulting electromagnetic forces from high currents without being damaged electrically or mechanically. Additional information can be found in IEC 61869-2. The equipment CT input circuits (conventional CT inputs) shall withstand limiting dynamic overcurrents for 0,5 cycle of rated power frequency with:

- no electrical safety and fire hazard risks;
- conformity with dielectric strength requirements before and after the test

Safety test requirements for protection equipment, with CTs rated 1 A and 5 A are given in Table 17.

Table 17 – Limiting dynamic values

Rated current (RMS)	Frequency	Thermal withstand (RMS) 100 × rated current		Limiting dynamic value (peak) 250 × rated current	
		Value	Duration	Value	Duration
1 A	16,7 Hz	100 A	1 s	250 A	30 ms
5 A	16,7 Hz	500 A	1 s	1 250 A	30 ms
1 A	25 Hz	100 A	1 s	250 A	20 ms
5 A	25 Hz	500 A	1 s	1 250 A	20 ms
1 A	50 Hz	100 A	1 s	250 A	10 ms
5 A	50 Hz	500 A	1 s	1 250 A	10 ms
1 A	60 Hz	100 A	1 s	250 A	8,3 ms
5 A	60 Hz	500 A	1 s	1 250 A	8,3 ms

9.6.5.4 Output relay parameters

The manufacturer shall test the output trip relay (including PCB track, terminal block, etc. connected to the output trip relay) to ensure performance meets the minimum requirements in accordance with IEC 60255-1 or the equipment manufacturer's published specification (if greater) except for parameters guaranteed by the relevant component manufacturer's specification.

9.6.5.5 Single fault condition

Refer to 4.10 for single fault condition assessment and 6.10.3 for conformity with the requirements for protection against the spread of fire when conducting a single fault type test on fully assembled equipment. It is sufficient to carry out a single fault test(s) on a particular module variation, once only, where the common module is used throughout a platform range. After the single fault, the dielectric testing shall be performed to ensure that the solid insulation has not been compromised.

The need for any single fault testing will depend on the result of the single fault condition assessment.

9.6.6 Reverse polarity and slow ramp test

The manufacturer shall test the power supply inputs to ensure that reverse application of the supply voltage does not cause any safety critical component to achieve a temperature outside its rated operating temperature at the equipment's maximum rated ambient temperature, spread of fire or risk of electrical shock. The assessment of fire risks shall be determined using methods of 6.10. The supply voltage shall be applied reverse polarity for at least 1 min to enable thermal equilibrium to be achieved for all safety critical components. This test is applicable for DC powered products only.

The manufacturer shall test the power supply inputs to ensure that slow variations in supply voltage do not cause any safety critical component to achieve a temperature outside of its rated operating temperature at the equipment's maximum rated ambient temperature, spread of fire or risk of electrical shock or damage of the product. The supply voltage shall be varied in accordance with Figure 4, and the safety critical components of the power supply shall be monitored to ensure that no safety critical component achieves a temperature outside of its rated operating temperature at the equipment's maximum rated ambient temperature during the test. During the testing, the equipment under test shall be in a quiescent state with half the binary inputs and outputs energized and communications ports exercised (where fitted). The supply voltage shall be varied with a defined gradient for ramp down and ramp up of 1 V/min in accordance with Figure 4. This test is applicable for DC powered products only.

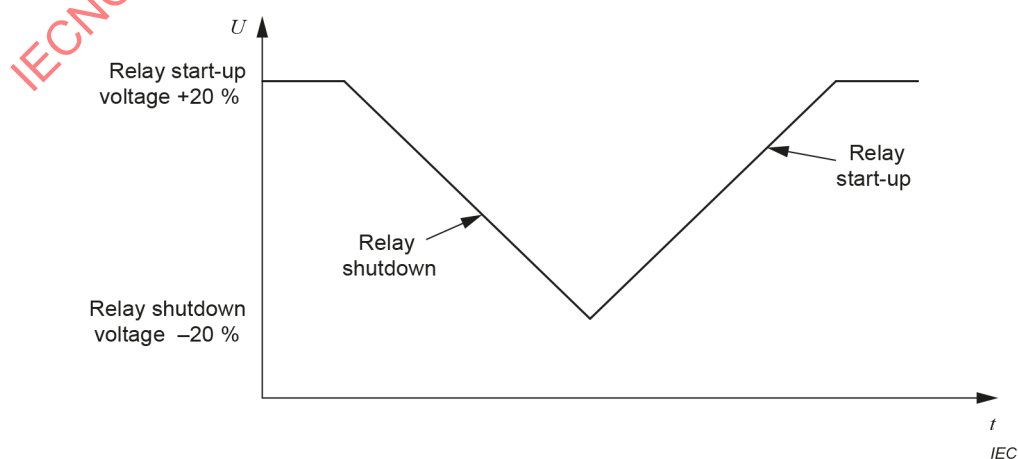


Figure 4 – Voltage ramp test

9.6.7 Resistance to mechanical stress

9.6.7.1 General

Equipment shall not cause a hazard when subjected to mechanical stresses likely to occur in normal use.

The normal energy protection level required is at least IK6 (1 J) (based on IEC 61010-1) provided that all the following criteria are met.

- a) When the equipment is installed in its intended application it cannot easily be touched by unauthorized persons.
- b) In normal use, the equipment is only accessed for occasional operations such as adjustment, programming or maintenance.

Conformity is checked by inspection and by performing each of the following tests on the parts of the enclosure accessible under normal use:

- 1) the static test of 9.6.7.2;
- 2) the impact test of 9.6.7.3 at the energy level specified above.

Parts which do not form part of an enclosure are not subjected to the tests of 9.6.7.2 and 9.6.7.3.

After the tests, visibly damaged windows and displays shall be inspected to check that hazardous-live-parts have not become accessible. In addition the equipment shall be inspected to check that:

- there have been no leaks of corrosive or harmful substances;
- enclosures show no cracks which could cause a hazard;
- clearances are not less than their permitted values;
- the insulation of internal wiring remains undamaged;
- protective barriers necessary for safety have not been damaged or loosened;
- no moving parts are exposed;
- there has been no damage which could cause spread of fire.

9.6.7.2 Static test

The equipment is held firmly against a rigid support and subjected to a force of 30 N applied by the hemispherical end of a hard rod of 12 mm diameter. The rod is applied to each part of the enclosure which could easily be touched when the equipment is ready for use.

In case of doubt whether a non-metallic enclosure will pass this test at an elevated temperature, this test is performed after the equipment is operated at the maximum rated ambient temperature, until a steady-state condition is reached. The equipment is disconnected from the supply source before the test is performed.

9.6.7.3 Impact test

Covers, etc., intended to be removed and replaced by an operator have their fixing screws tightened using a torque likely to be applied in normal use. With the equipment held firmly against a rigid support, the impact is applied to all points on surfaces which are easily touched in normal use and which would be likely to cause a hazard if damaged.

NOTE A support is considered to be sufficiently rigid if its displacement is less than or equal to 0,1 mm under the effect of an impact directly applied and whose energy corresponds to the degree of protection.

Non-metallic enclosures of equipment with a minimum rated ambient temperature below 2 °C are cooled to the minimum rated ambient temperature, then tested within 10 min.

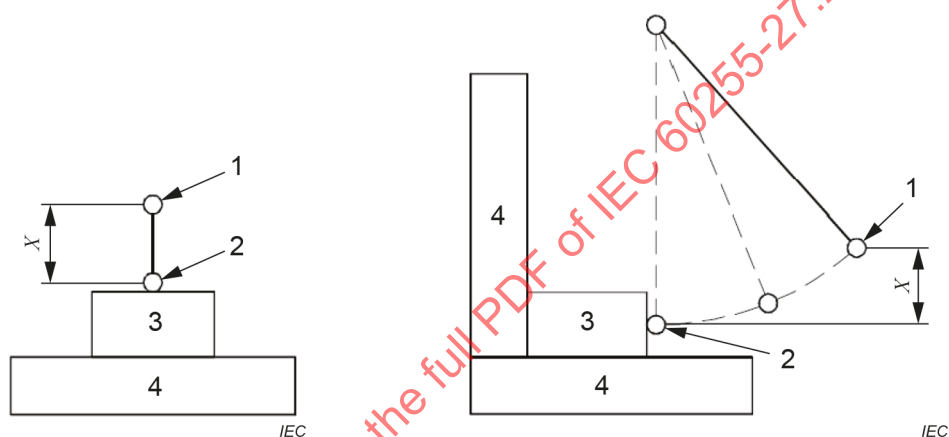
If an enclosure is damaged by an impact but meets the pass criteria, a new enclosure may be used for the next impact.

Fixed equipment is mounted as specified in the installation instructions. Other equipment is held firmly against a rigid support and each test point is subjected to one impact by a smooth steel sphere with a mass $500\text{ g} \pm 25\text{ g}$ and with a diameter of approximately 50 mm.

The impact test can be performed using the method shown in Figure 5 a) or Figure 5 b).

Figure 5 a) shows the impact applied to a horizontal surface, with the sphere allowed to fall freely from a height of 200 mm. The equipment can be mounted at 90° to its normal position to allow this method to be used.

Figure 5 b) shows the impact applied to a vertical surface, with the sphere suspended by a cord and allowed to fall as a pendulum through a vertical distance of 200 mm.



a) Impact applied to a horizontal surface

- 1 Sphere start position
- 3 Test sample
- X Vertical fall distance. See Table 18.

b) Impact applied to a vertical surface

- 2 Sphere impact position
- 4 Rigid supporting surfaces

Figure 5 – Impact test with sphere

Table 18 – Impact energy levels, test height and corresponding IK codes

	Impact energy level (J) and IK code		
	1 (IK06)	2 (IK07)	3 (IK08)
Vertical fall distance, X (mm)	200	400	1 000

Annex A (normative)

Isolation class requirements and example diagrams

A.1 General

This Annex A provides guidance on the isolation class and insulation requirements for different circuit types, with typical insulation examples. The isolation requirements, in conjunction with reference to 6.7 of IEC 61010-1:2010 and of IEC 61010-1:2010/AMD1:2016, and Annex B of IEC 61010-1:2010, shall be used to determine the required clearances and creepage distances from Annex C.

ELV, PEB, PELV and SELV circuits provide protection from electric shock from hazardous live voltages and are not necessarily related to protective class I, II or III equipment class.

A.2 Hazardous live voltage (HLV)

Hazardous live voltage applies to the following:

- voltage transformers, current transformers, output relays;
- connection to the AC or DC supply;
- analogue and digital inputs and outputs exceeding 30 V AC RMS or 60 V DC.

Table A.1 – Circuit isolation class for product circuits and/or groups

Circuit isolation class	Product circuits and/or groups
ELV Extra low voltage	Non-primary circuits complying with the following under normal use: • not exceeding 30 V AC RMS or 60 V DC, below ELV voltage limits; • separated from HLV by at least basic insulation. See Figure A.4. ELV circuits should not be accessible under normal use. Examples are: • non-primary circuits; • analogue and/or digital inputs and outputs, complying with ELV voltage limits; • connections to ELV terminations of other products.
SELV Safety extra low voltage	Non-primary circuits complying with ELV voltage limits and the following conditions: • separated from HLV by reinforced or double insulation; • there is no provision for an earth connection. See Figure A.1. SELV circuits may be accessible and are safe to touch under both normal and single fault conditions. Connection of an earth to a SELV circuit is not permitted; for example, connection to an earthed cable screen or earthed wired network port is not permitted. Where this is required, the circuit definition should change in accordance with Figure A.2 (PELV). An exception could be for a PELV system earthed at one end of a cable run; it would be permissible to connect a SELV system at the other end. Examples are: • analogue and/or digital inputs and outputs which can be connected direct to unearthed wired network port; • SELV ports which are suitable for connection to SELV ports of other products.

Circuit isolation class	Product circuits and/or groups
PELV Protective extra low voltage	Non-primary circuits complying with ELV voltage limits and the following conditions: • separated from HLV by reinforced or double insulation; • connected to functional earth, the protective (earth) conductor, or have provision for an earth connection. See Figure A.2. PELV circuits may be accessible and are safe to touch under both normal and single fault conditions. Examples are: • Analogue and/or digital inputs and outputs which can be connected direct to wired network port; • PELV ports which are suitable for connection to PELV ports of other products.
PEB Protection by equipotential bonding	Non-primary circuits complying with ELV voltage limits and the following conditions: • basic protection against electric shock is provided by basic insulation separating HLV from PEB circuits; • for fault protection, PEB circuits and accessible conductive parts, are bonded to the protective conductor terminal and comply with 9.6.4.5.1, which will prevent hazardous live voltages in PEB circuits. See Figure A.3. PEB circuits may be accessible and are safe to touch under both normal and single fault conditions. PEB circuits may be considered as protective earthed circuits or earthed accessible parts for the purposes of Table A.2. Examples are: • analogue and/or digital inputs and outputs which can be connected direct to wired network port and LPVT, LPIT, LPCT connections; • PEB ports which are suitable for connection to PEB ports of other products.
Functional earth	Non-primary circuits complying the following conditions: • separated from ELV, PEB and PELV circuits by at least functional insulation; • separated from parts at hazardous voltage in the equipment by either: – double insulation or reinforced insulation; or – a protectively earthed screen or another protectively earthed conductive part, separated from parts at hazardous voltages by at least basic insulation. It is permitted to connect the functional earthed circuit to a protective conductor terminal or to a protective bonding conductor.
The symbols of this table are explained in Clause A.3.	

A.3 Symbols

The following symbols are used in Table A.1 and Figure A.1 to Figure A.4.

a) Requirements

- B: basic insulation or supplementary insulation
- D: double insulation or reinforced insulation
- F: functional insulation

b) Circuits and parts

- A: accessible part, not bonded to the protective conductor terminal
- C: equipment case
- ELV: circuit or part for which, under normal use, the ELV voltage limits in Table A.1 are not exceeded
- HLV: circuit or part that is hazardous live under normal use, as defined in 3.22

PEB, PELV, SELV: circuits that are safe to touch under both normal and single fault conditions, as defined in Table A.1

Z: impedance of secondary circuit.

Table A.2 – Insulation requirement between any two circuits

	HLV primary circuit^a	ELV circuit	SELV circuit	PELV circuit	PEB circuit^b	Protective earthed HLV non-primary circuit^{b,c}	Unearthed HLV non-primary circuit^c
HLV primary circuit^a	F/B ^{a,f} (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)	B ^e (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)
ELV circuit	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^{e,f} (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)
SELV circuit	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	F/B ^h (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)
PELV circuit^b	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	F/B ^h (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)
PEB circuit^b	B ^e (Table C.4 to Table C.7)	F/B ^{e,f} (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^e (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)
Protective earthed HLV non-primary circuit^{b,c}	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)
Unearthed HLV non-primary circuit^c	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)

	HLV primary circuit ^a	ELV circuit	SELV circuit	PELV circuit	PEB circuit ^b	Protective earthed HLV non- primary circuit ^{b,c}	Unearthed HLV non- primary circuit ^c
Unearthed accessible parts^g	D (Table C.8 to Table C.11)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	D (Table C.8 to Table C.11)	B/D ^d (Table C.4 to Table C.7) / (Table C.7 to Table C.10)
Protective earth^{b,g} / Protective earthed accessible parts^{b,g}	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	F/B ^f (Table C.2 to Table C.7) / (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)	B (Table C.4 to Table C.7)

The symbols are explained in Clause A.3.

See Clause A.2 for typical circuit insulation requirements.

Table C.2 to Table C.11 are shown in brackets in Table A.2. The choice of these tables depends on the overvoltage category and the pollution degree.

^a If the functional voltage (not relative to earth) is greater than the rated insulation voltage, the creepage distance for the functional insulation may be greater than that of the basic insulation. One example is a terminal block where the functional phase to phase voltage is 400 V AC RMS. For a comparative tracking index (CTI) of 100 to 399, the creepage distance for 400 V functional insulation is 4,0 mm (Table C.3) compared with 3,0 mm (Table C.7) for 230 V AC RMS phase to ground (300 V basic insulation).

^b Connections to the protective conductor shall comply with 9.6.4.5.1; otherwise, this shall be considered to be an unearthed circuit.

^c There shall be at least basic insulation between HLV non-primary circuits and HLV primary circuits.

^d Insulation between an unearthed non-primary circuit at hazardous voltage and an unearthed accessible conductive part (B/D in Table A.2) shall satisfy the more onerous of the following:

- double or reinforced insulation, the working voltage of which is equal to the hazardous voltage; or
- supplementary insulation, the working voltage of which is equal to the voltage between the non-primary circuit at hazardous voltage; and
 - another non-primary circuit at hazardous voltage; or
 - a primary circuit.

^e See Figure A.3 for the conditional use of basic insulation for PEB.

^f Supplementary or basic insulation shall be used if one of the circuits is an independent circuit or is adjacent to a conductive part which is earthed when the equipment is installed. The insulation requirement will depend on the overvoltage category. The normal overvoltage category for equipment is overvoltage category III (Table C.6 or Table C.7); however, in some applications, where transients are limited to overvoltage category II, Table C.4 or Table C.5 may be applied if the equipment is supplied from one of the following:

- a battery* with no protective relays or measuring equipment connected; or
- the AC* supply of an office environment.

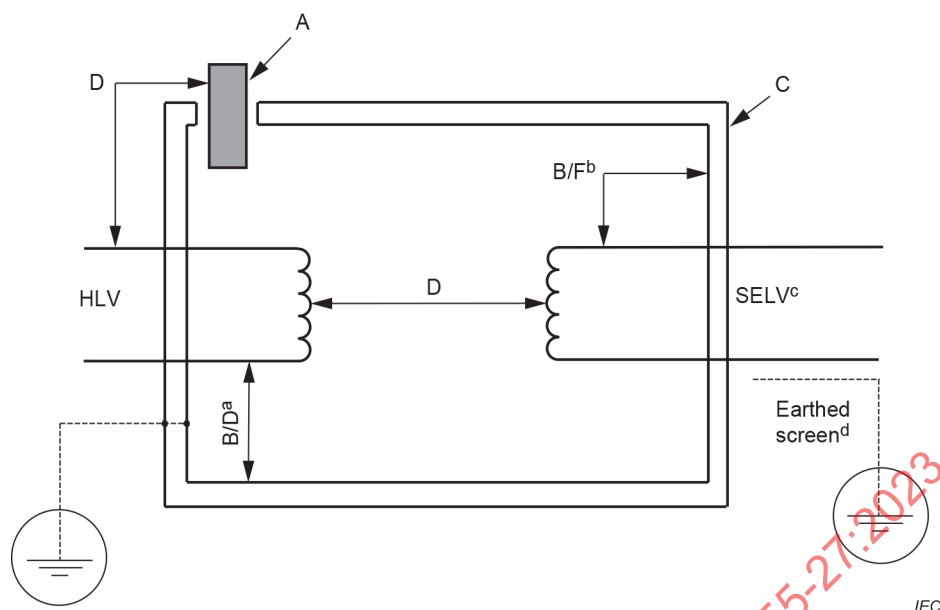
* The maximum transient voltage amplitude on the supply shall be $2\,500\text{ V}_{\text{peak}}$.

^g A functional earthed circuit shall be treated as an unearthed accessible part. The exception is where the functional earth is bonded to the protective conductor and this meets protective bonding resistance requirements, then it may be treated as an earthed accessible part.

^h For a PELV system earthed at one end of a cable run, it would be permissible to connect a SELV system at the other end.

A.4 Typical insulation examples complying with the requirements of Table A.2

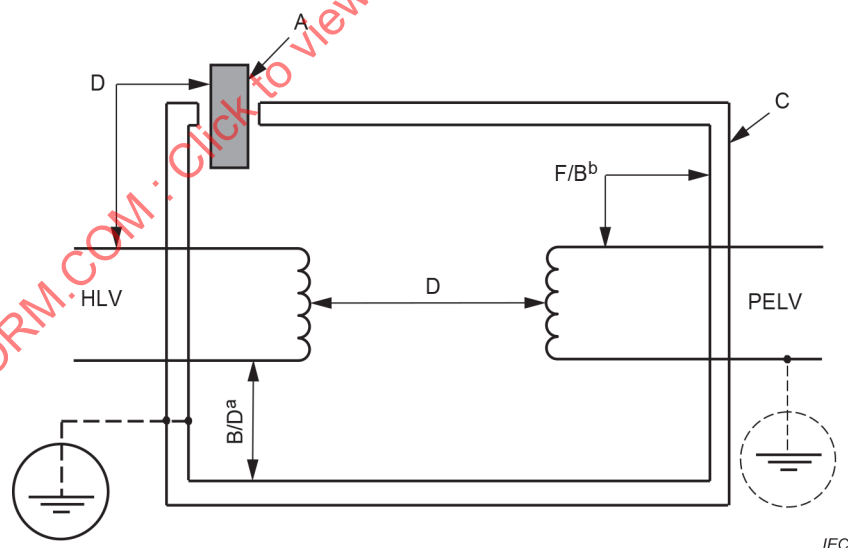
Refer to Table A.2 for the insulation requirements between different circuits and/or parts.



The symbols are explained in Clause A.3.

- ^a If the case and/or accessible parts are conductive and connected to the protective conductor terminal, only basic insulation (B) is required between these and HLV. Otherwise, double insulation (D) is required between case and/or accessible parts and HLV.
- ^b If the case is conductive, basic insulation (B) shall be used between it and the SELV circuit; otherwise, functional insulation (F) may be used.
- ^c Connection of an earth to a SELV circuit is not permitted.
- ^d If the SELV is screened cable then the outer screen can be connected to earth provided the screen and SELV circuit are separated by basic insulation.

Figure A.1 – Equipment with SELV input and/or output (I/O)

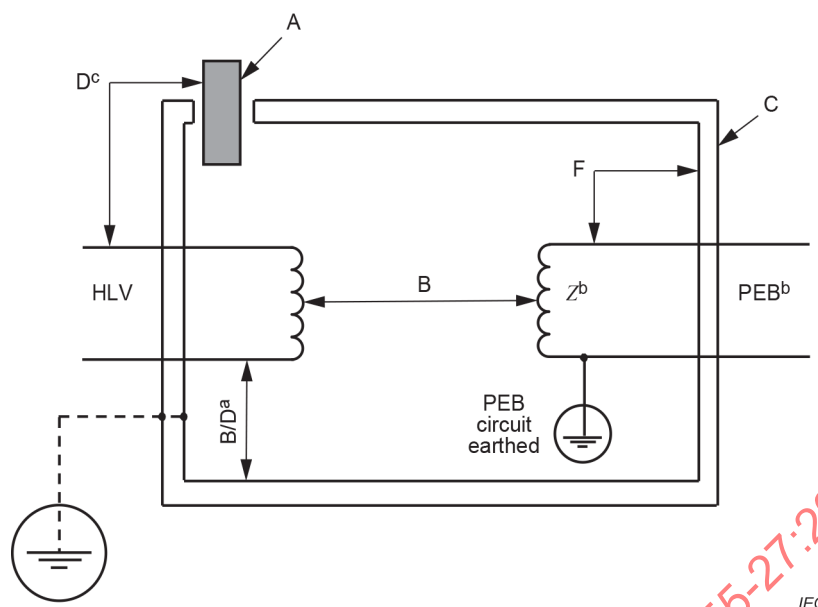


The symbols are explained in Clause A.3.

It is only permissible to connect an earth conductor to class II equipment for functional or EMC purposes, for example, an earthed cable screen; however, this screen shall be protected from adjacent circuits by basic insulation, rated for the adjacent circuit voltage.

- ^a If the case and/or accessible parts are conductive and connected to the protective conductor terminal, only basic insulation (B) is required between these and HLV parts. Otherwise, double insulation (D) is required between case and/or accessible parts and HLV parts.
- ^b If the case is conductive and unearthed, basic insulation (B) shall be used between it and the PELV circuit; otherwise, functional insulation (F) may be used.

Figure A.2 – Equipment with PELV input and/or output (I/O)

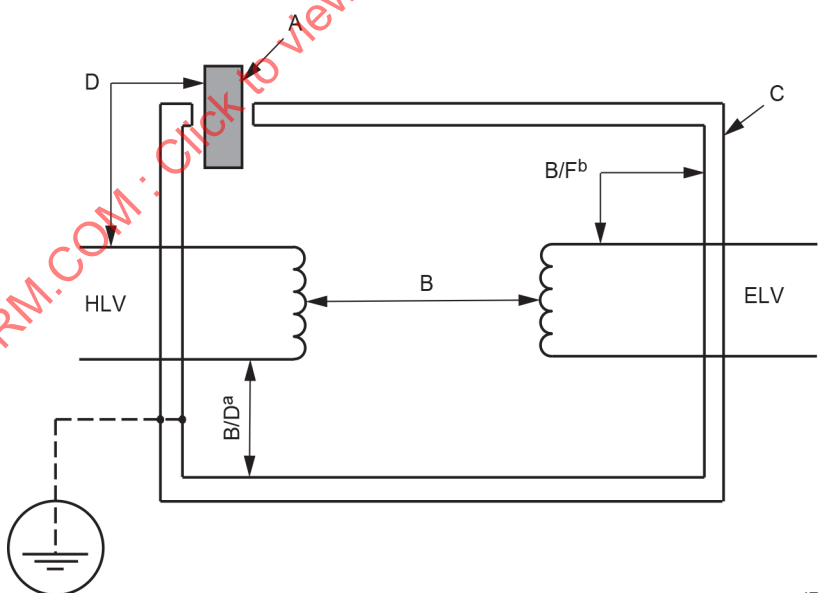


IEC

The symbols are explained in Clause A.3.

- ^a If the case and/or accessible parts are conductive and connected to the protective conductor terminal, only basic insulation (B) is required between these and HLV parts. Otherwise, double insulation (D) is required between case and/or accessible parts and HLV parts.
- ^b The connection path of the PEB circuit to the protective conductor terminal, including impedance Z , shall comply with 9.6.4.5.1. Then, if under a single fault condition, an HLV conductor was shorted to the PEB circuit, the PEB circuit would not become hazardous live.
- ^c If the case and/or parts are non-conductive, there shall be double insulation (D) between HLV circuits and/or parts and the applied rigid test finger (IEC 61010-1:2010, Figure B.1).

Figure A.3 – Equipment with PEB input and/or output (I/O)



IEC

The symbols are explained in Clause A.3.

- ^a If the case and/or accessible parts are conductive and connected to the protective conductor terminal, only basic insulation (B) is required between these and HLV parts. Otherwise, double insulation (D) is required between case and/or accessible parts and HLV parts.
- ^b If the case is conductive, basic insulation (B) shall be used between it and the ELV circuit; otherwise, functional insulation (F) may be used.

Figure A.4 – Equipment with ELV input and/or output (I/O)

Annex B (normative)

Rated impulse voltages

The purpose of this Annex B is to provide information on the withstand requirements for voltage impulses, which can appear on the supply lines, relative to neutral and/or earth. The rated supply or working voltages can be determined using 6.7 of IEC 61010-1:2010 and of IEC 61010-1:2010/AMD1:2016.

The relevant rated voltage and overvoltage category are used, together with the pollution degree, to select the appropriate table in Annex C for the determination of clearances and creepage distances, for safety reasons. For most applications 300 V and overvoltage category III are applicable (see C.1.2).

The impulse voltages for non-conventional input transformers are specified in IEC 61869-6, IEC 61869-10 and IEC 61869-11. Applicable insulation requirement for LPIT inputs of the protection equipment shall be checked from Table A.2 and test voltages from Table C.2 to Table C.11.

The rated impulse voltage determines the clearance in air.

Table B.1 – Rated impulse voltages (waveform: 1,2/50 μ s)

Voltage line to neutral derived from rated or working voltages AC RMS or DC up to and including ^{a,b} V	Rated impulse voltage ^c V		
	Overvoltage category		
	I	II	III ^d
50	330	500	800
100	500	800	1 500
150	800	1 500	2 500
300	1 500	2 500	4 000
600	2 500	4 000	6 000
1 000	4 000	6 000	8 000

^a The line to neutral voltages are preferred values (see IEC 61010-1:2010 and IEC 61010-1:2010/AMD1:2016, Annex K) for application to existing different low-voltage supplies and their rated voltages.

^b The rated impulse voltages are given for an altitude of 2 000 m; see Table C.12 for the multiplication factor for the test voltage at higher altitudes.

^c Interpolation of the rated impulse voltage is not permissible for circuits connected to primary circuits.

^d Overvoltage category IV values are given in IEC 60664-1:2020, Annex B.

Annex C

(normative)

Guidance for the determination of clearance, creepage distance and withstand voltages

C.1 General

C.1.1 Introductory remark

This Annex C provides guidance for the determination of the minimum clearances, creepage distances and withstand voltages for equipment insulation, including the effect of altitude.

Clearances and creepage distances shall be selected after consideration of the following influences:

- pollution degree;
- overvoltage category;
- rated insulation voltage;
- insulation requirement (functional, basic, double and reinforced);
- location of insulation (for example, subject to mechanical stresses, etc.).

Basic insulation provides basic protection against electric shock and is normally determined for the working voltage relative to earth, for the appropriate overvoltage category, which determines the impulse voltage rating.

Functional insulation is required for the functioning of the equipment and does not provide protection against electric shock. The impulse voltage generally has little influence in the determination of functional insulation; Table C.3 or Table C.2 is normally appropriate. However, other tables, for example, Table C.4 to Table C.7, may be appropriate according to the transient or impulse voltages which can be seen across the functional circuit. Therefore, Table C.4 to Table C.7 is applicable to functional insulation or basic insulation or supplementary insulation.

The clearance and creepage distance requirements for the interior solid insulation of void-free moulded parts, including the inner layers of multi-layer printed circuit boards, are detailed in IEC 61010-1. Solid insulation shall be proven by dielectric voltage testing in accordance with 9.6.4.3 or checked by measurement of the insulation thickness and inspection of the manufacturer's specifications.

The minimum creepage distance shall not be less than the minimum clearance in air. These clearance and creepage distances are minimum values; manufacturing tolerances shall additionally be taken into account.

C.1.2 Rated insulation voltages

The rated insulation voltage of one or all of the equipment's circuits can be determined from the tables in this Annex C. However, for equipment energized direct from instrument transformers and for circuits to be connected direct to the station battery supply, the rated insulation voltage shall not be less than 250 V; this is applicable for energizing voltages between 0 V and 250 V. If a 24 V or 48 V battery was used for communication purposes only, for example with no measuring relays or protection equipment connected to the battery supply, then according to Table C.1, 50 V is the appropriate working voltage and the associated impulse voltage for overvoltage category III is $800 V_{peak}$. However, IEC 62151 shall be used to determine if a higher overvoltage relevant to connection to a wired network port is applicable.

The rated impulse voltage of equipment energized direct from the low-voltage AC supply shall be selected from Table B.1 corresponding to the overvoltage category (normally III) specified and the rated voltage of the equipment.

For basic, supplementary, reinforced and double insulation, the voltage values in column 1 of Table C.4 to Table C.11 are relative to earth and/or neutral (Table C.2 and Table C.3 are specifically for the working voltage of functional insulation and may not be relative to earth and/or neutral).

The rated insulation for non-conventional input transformers is specified in IEC 61869-6, IEC 61869-10 and IEC 61869-11. Applicable insulation requirement for LPIT inputs of the protection equipment shall be checked from Table A.2 and test voltages from Table C.2 to Table C.11.

C.1.3 Determination of rated insulation voltage

The rated insulation voltage shall be determined as follows:

- a) for insulation between live parts and accessible conductive parts, not less than the rated voltage of the circuit under consideration;
- b) for insulation between the parts of one circuit, except as provided in item e), not less than the rated voltage of the circuit under consideration;
- c) for insulation between parts of two independent circuits, the rated insulation voltage should be at least equal to the higher rated voltage of these circuits;
- d) for gaps between open contacts, unless otherwise agreed between manufacturer and user, no rated insulation voltage is specified;
- e) for circuits of an equipment having rated voltages exceeding 1 000 V, Annex A of IEC 60664-1:2020 shall be used for determining clearances, creepage distances and withstand voltages.

The rated insulation voltage shall be determined from IEC 60664-1, with reference to C.1.2 of this document for the minimum applicable rating for some circuits.

C.1.4 Determination of rated impulse voltage

C.1.4.1 General

Transient overvoltages as expected during operation are taken as the basis for determining the rated impulse voltage (see 4.9.2.2 for primary circuits and 4.9.2.3 for non-primary circuits, and for the test reference).

Firstly, the rated insulation voltage shall be determined, see C.1.3.

The rated insulation voltage and applicable overvoltage category shall then be used in Table B.1 to determine the rated impulse voltage.

C.1.4.2 Selection of rated impulse voltage

The rated impulse voltage of equipment shall be determined using 6.7 of IEC 61010-1:2010/AMD1:2016 and Table B.1 of this document corresponding to the overvoltage category specified and to the rated voltage of the equipment.

C.1.4.3 Impulse voltage insulation coordination within the equipment

For parts or circuits within the equipment which are significantly influenced by external transient overvoltages, the rated impulse voltage of the equipment applies. Transient overvoltages which can be generated by the operation of the equipment shall not influence external circuit conditions beyond that specified in C.1.5.

For other parts or circuits within the equipment which are specifically protected against transient overvoltages, by transient suppression, so that they are not significantly influenced by external transient overvoltages, the impulse voltage withstand required for insulation is not related to the rated impulse voltage of the equipment but to the actual conditions for that part or circuit and the clearance shall be determined from the appropriate Table C.2 to Table C.11. The transient protected circuit shall however comply with the test requirements in 9.6.3. However, the overall overvoltage category of the circuit cannot be reduced unless suitable transient suppression is employed for both differential and common modes.

C.1.5 Switching overvoltages generated by equipment

For equipment capable of generating an overvoltage at its terminals, for example switching devices, the rated impulse voltage implies that the equipment shall not generate overvoltages in excess of this value when used in accordance with the relevant standard and instructions of the manufacturer. Otherwise, the user shall provide measures to limit the impact of the switching overvoltages.

C.1.6 Insulation material

Comparative tracking index (CTI) values are used to categorize insulation materials as specified in Table C.1.

Table C.1 – Comparative tracking index (CTI)

Material group	CTI range
I	$600 \leq \text{CTI}$
II	$400 \leq \text{CTI} < 600$
IIIa	$175 \leq \text{CTI} < 400$
IIIb	$100 \leq \text{CTI} < 175$

For inorganic insulating materials, for example, glass or ceramics which do not track, creepage distances need not be greater than their associated clearances. However, the risk of disruptive discharge should be considered.

C.1.7 Overvoltage categories

The applicable overvoltage category shall be determined based on the following criteria.

a) Category I

This category applies to equipment where special measures are taken to limit transient voltages to appropriate values, for example, well-protected electronic circuits. To claim category I, the special voltage measures should apply to both common and differentially connected circuits.

b) Category II

This category applies to some cases of the application of equipment and shall be used where:

- 1) the auxiliary energizing circuits (power supply circuits) of the equipment are connected to a voltage supply used only for the power supply of static equipment. This is only the case if the leads are short and there is an absence of switching of other circuits connected to the AC or DC supply. The levels of transient voltage on the supply leads will be lower than specified in overvoltage category III;
- 2) the input energizing circuits of the equipment are not connected direct to voltage or current transformers, and good screening and earthing is employed on the connection leads;
- 3) the output circuits are connected to a load by short lead lengths.

c) Category III

This category applies to most practical cases of the application of equipment and shall be used where:

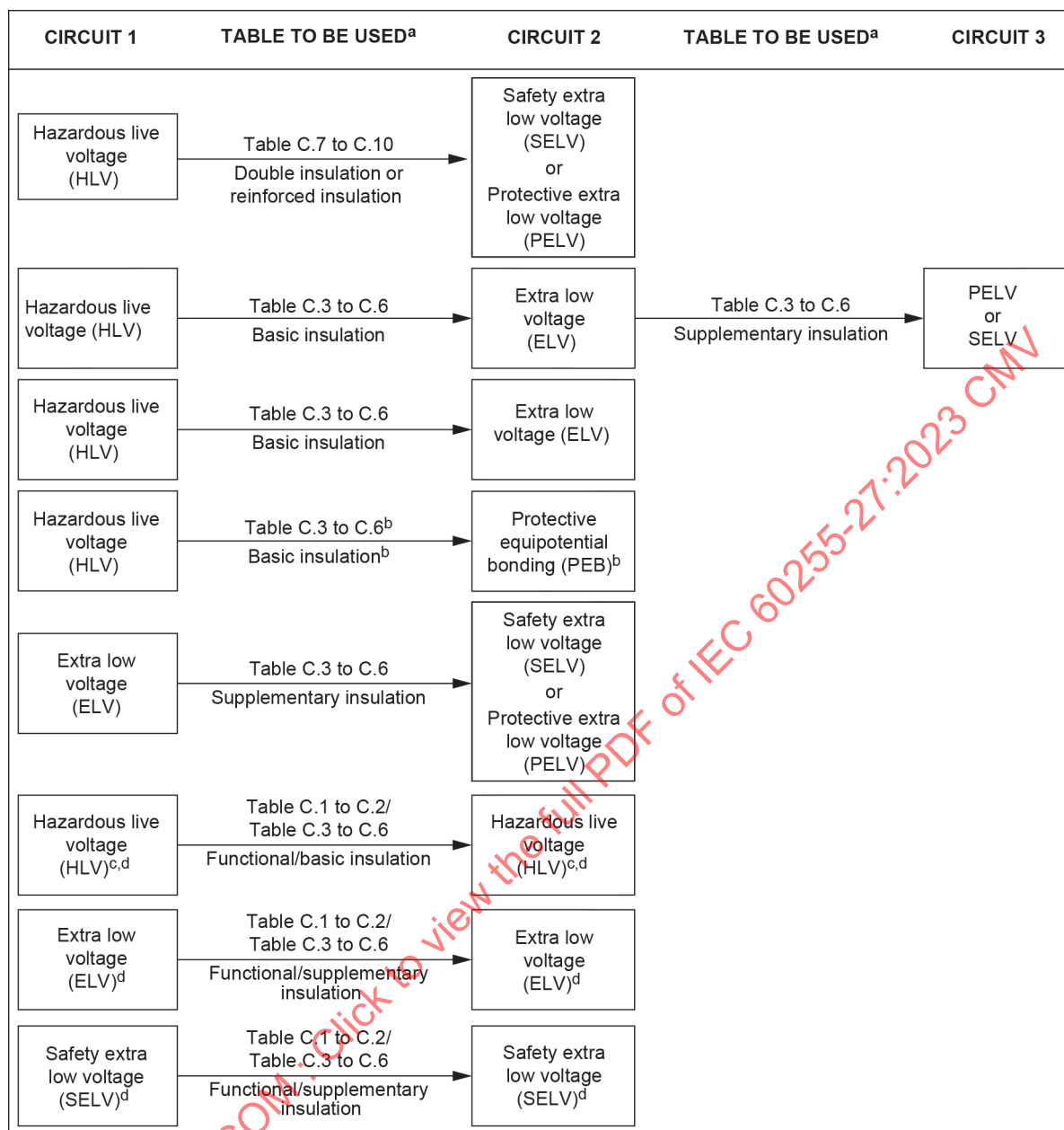
- 1) the auxiliary energizing circuits (power-supply circuits) of the equipment are connected to a common battery and/or, due to long lead lengths, common mode transient overvoltages of a relatively high value can appear on the supply leads, and differential mode voltages can arise from switching in other circuits connected to the same battery or supply source;
- 2) the input energizing circuits of the equipment are connected to current and voltage transformers;
- 3) the output circuits are connected to a load by long leads with the result that common mode transient voltages of a relatively high value can appear at the output terminals.

C.2 Determination of clearances, creepage distances and withstand voltages

C.2.1 Guidance for determination of clearances, creepage distances and withstand voltages

See Figure C.1.

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^a Select the tables according to overvoltage category and pollution degree.

^b Provided that the PEB circuit cannot become hazardous live (see Figure A.3).

^c If the functional voltage (not relative to earth) is greater than the rated insulation voltage, the creepage distance for the functional insulation may be greater than that of the basic insulation. One example is a terminal block where the functional phase to phase voltage is 400 V AC RMS. Adhere to the minimum clearance for rated 4 kV peak impulse for 300 V basic insulation, but use Annex B of IEC 60664-1:2020 to determine creepage distance for functional phase to phase voltage.

^d Supplementary or basic insulation (Table C.4 to Table C.7) shall be used if one of the circuits is an independent circuit, for example, where a withstand of 2 kV AC RMS for 1 min is required, by specification, between the two circuits.

Figure C.1 – Guidance for determination of clearances, creepage distances and withstand voltages

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category I					
	Creepage distance mm		Clearance mm	Withstand voltage V		
	In equipment CTI ≥ 100	On printed ^a circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,18	0,025	0,01	330	230	330
100	0,25	0,10	0,04	500	350	500
150	0,31	0,22	0,10	800	490	700
300	0,70	0,70	0,50	1 500	820	1 150
600	1,68	1,68	1,50	2 500	1 350	1 900
1 000	3,20	3,20	3,00	4 000	2 200	3 100

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For altitude correction to be applied, see Table C.12.

Table C.3 – Functional insulation, pollution degree 2, overvoltage category I

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category I								
	Creepage distance mm					Clearance mm	Withstand voltage V		
	In equipment			On printed circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	0,60	0,85	1,20	0,04	0,025	0,20	330	230	330
100	0,71	1,00	1,40	0,16	0,10	0,20	500	350	500
150	0,79	1,09	1,57	0,36	0,22	0,20	800	490	700
300	1,50	2,10	3,00	1,43	0,70	0,50	1 500	820	1 150
600	3,00	4,30	6,00	3,04	1,68	1,50	2 500	1 350	1 900
1 000	5,00	7,10	10,00	5,00	3,20	3,00	4 000	2 200	3 100

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b See C.2.2 for minimum coating requirements.

^c For altitude correction to be applied, see Table C.12.

Table C.4 – Functional, basic or supplementary insulation, pollution degree 1, overvoltage category II

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category II					
	Creepage distance mm		Clearance mm	Withstand voltage V		
	In equipment CTI ≥ 100	On printed ^a circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,18	0,025	0,04	500	350	500
100	0,25	0,10	0,10	800	490	700
150	0,31	0,22	0,50	1 500	820	1 150
300	0,70	0,70	1,50	2 500	1 350	1 900
600	1,68	1,68	3,00	4 000	2 200	3 100
1 000	3,20	3,20	5,50	6 000	3 250	4 600

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For altitude correction to be applied, see Table C.12.

Table C.5 – Functional, basic or supplementary insulation, pollution degree 2, overvoltage category II

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category II								
	Creepage distance mm					Clearance mm	Withstand voltage V		
	In equipment			On printed circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	0,60	0,85	1,20	0,04	0,20	0,20	500	350	500
100	0,71	1,00	1,40	0,16	0,20	0,20	800	490	700
150	0,79	1,09	1,57	0,36	0,22	0,50	1 500	820	1 150
300	1,50	2,10	3,00	1,43	0,70	1,50	2 500	1 350	1 900
600	3,00	4,30	6,00	3,04	1,68	3,00	4 000	2 200	3 100
1 000	5,00	7,10	10,00	5,00	3,20	5,50	6 000	3 250	4 600

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b See C.2.2 for minimum coating requirements.

^c For altitude correction to be applied, see Table C.12.

Table C.6 – Functional, basic or supplementary insulation, pollution degree 1, overvoltage category III

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category III					
	Creepage distance mm		Clearance mm	Withstand voltage V		
	In equipment CTI ≥ 100	On printed ^a circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,18	0,025	0,10	800	490	700
100	0,25	0,10	0,50	1 500	820	1 150
150	0,31	0,22	1,50	2 500	1 350	1 900
300	0,70	0,70	3,00	4 000	2 200	3 100
600	1,68	1,68	5,50	6 000	3 250	4 600
1 000	3,20	3,20	8,00	8 000	4 350	6 150

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For altitude correction to be applied, see Table C.12.

Table C.7 – Functional, basic or supplementary insulation, pollution degree 2, overvoltage category III

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category III								
	Creepage distance mm					Clearance mm	Withstand voltage V		
	In equipment			On printed circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100						
50	0,60	0,85	1,20	0,04	0,025	0,20	800	490	700
100	0,71	1,00	1,40	0,16	0,10	0,50	1 500	820	1 150
150	0,79	1,09	1,57	0,36	0,22	1,50	2 500	1 350	1 900
300	1,50	2,10	3,00	1,43	0,70	3,00	4 000	2 200	3 100
600	3,00	4,30	6,00	3,04	1,68	5,50	6 000	3 250	4 600
1 000	5,00	7,10	10,00	5,00	3,20	8,00	8 000	4 350	6 150

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b See C.2.2 for minimum coating requirements.

^c For altitude correction to be applied, see Table C.12.

Table C.8 – Double or reinforced insulation, pollution degree 1, overvoltage category II

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category II					
	Creepage distance mm		Clearance mm	Withstand voltage V		
	In equipment CTI ≥ 100	On printed ^a circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
50	0,36	0,05	0,10	800	490	700
100	0,50	0,20	0,50	1 500	820	1 150
150	0,62	0,44	1,50	2 500	1 350	1 900
300	1,40	1,40	3,00	4 000	2 200	3 100
600	3,36	3,36	5,50	6 000	3 250	4 600
1 000	6,40	6,40	8,00	8 000	4 350	6 150

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For altitude correction to be applied, see Table C.12.

Table C.9 – Double or reinforced insulation, pollution degree 2, overvoltage category II

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category II								
	Creepage distance mm					Clearance mm	Withstand voltage V		
	In equipment			On printed circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	1,20	1,70	2,40	0,08	0,05	0,20	800	490	700
100	1,42	2,00	2,80	0,32	0,20	0,50	1 500	820	1 150
150	1,57	2,17	3,14	0,71	0,45	1,50	2 500	1 350	1 900
300	3,00	4,17	6,00	2,86	1,39	3,00	4 000	2 200	3 100
600	6,08	8,58	12,00	6,08	3,37	5,50	6 000	3 250	4 600
1 000	10,00	14,20	20,00	10,00	6,40	8,00	8 000	4 350	6 150

a Also applies to PCB-mounted components with mechanically stable distances between leads.

b See C.2.2 for minimum coating requirements.

c For altitude correction to be applied, see Table C.12.

Table C.10 – Double or reinforced insulation, pollution degree 1, overvoltage category III

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 1 – Overvoltage category III					
	Creepage distance mm		Clearance mm	Withstand voltage V		
	In equipment CTI ≥ 100	On printed ^a circuit board CTI ≥ 100		Peak impulse ^b 1,2/50 μs	RMS 50/60 Hz 1 min	DC 1 min
50	0,36	0,05	0,50	1 500	820	1 150
100	0,50	0,20	1,50	2 500	1 350	1 900
150	0,62	0,44	3,00	4 000	2 200	3 100
300	1,40	1,40	5,50	6 000	3 250	4 600
600	3,36	3,36	8,00	8 000	4 350	6 150
1 000	6,40	6,40	14,00	12 000	6 500	9 200

^a Also applies to PCB-mounted components with mechanically stable distances between leads.

^b For altitude correction to be applied, see Table C.12.

Table C.11 – Double or reinforced insulation, pollution degree 2, overvoltage category III

Rated insulation voltage or working voltage (RMS or DC) up to V	Pollution degree 2 – Overvoltage category III								
	Creepage distance mm					Clearance mm	Withstand voltage V		
	In equipment			On printed circuit board			Peak impulse ^c 1,2/50 µs	RMS 50/60 Hz 1 min	DC 1 min
	Material group			Not coated	Coated ^{a,b}				
	I CTI ≥ 600	II CTI ≥ 400	III CTI ≥ 100	CTI ≥ 175	CTI ≥ 100				
50	1,20	1,70	2,40	0,08	0,05	0,50	1 500	820	1 150
100	1,42	2,00	2,80	0,32	0,20	1,50	2 500	1 350	1 900
150	1,57	2,17	3,14	0,71	0,45	3,00	4 000	2 200	3 100
300	3,00	4,17	6,00	2,86	1,39	5,50	6 000	3 250	4 600
600	6,08	8,58	12,00	6,08	3,37	8,00	8 000	4 350	6 150
1 000	10,00	14,20	20,00	10,00	6,40	14,00	12 000	6 500	9 200
a Also applies to PCB-mounted components with mechanically stable distances between leads.									
b See C.2.2 for minimum coating requirements.									
c For altitude correction to be applied, see Table C.12.									

Table C.12 – Test site correction factor for proving the clearance in air

Test site altitude m	0	500	1 000	1 500	2 000	3 000	4 000	5 000
Test voltage multiplication factor	1,20	1,15	1,10	1,05	1	0,87	0,77	0,67

Table C.13 – Reduction of the pollution degree of internal environment through the use of additional protection within the equipment

Additional protection within the equipment	From pollution degree 2 of external environment to ^d	From pollution degree 3 of external environment to ^d
Constantly heated ^a	1	1
Encapsulated ^b	1	1
Coated ^c	1	2
Case hermetically sealed	1	1
Case protection meets IPX4 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013	2	2
^a This can be applied if the internal ambient temperature rise within the equipment is at least 5 °C. ^b Encapsulated: these are parts, including tracks and pads on the inner layers of printed circuit boards, which have been totally covered in an encapsulation material such as epoxy resin, and this is considered as solid insulation. This encapsulation provides a barrier between any condensation on the surface of the encapsulant and the surfaces of components and conductors which are encapsulated. ^c Coated: applies to printed circuit conductors covered by solder resist or to conductors or components which have been covered by a conformal coating. ^d If Table C.13 is used to determine reduced creepage distance, it should be ensured that this is not less than the minimum allowed clearance.		

Annex D (informative)

Components

D.1 General

This Annex D provides guidance for components which could cause safety risks if not adequately designed and constructed.

Consideration should be given to the fact that, on a long-term basis, the electrical and mechanical properties of some insulating materials can be adversely affected, for example, by softeners evaporating at temperatures below the normal softening temperature of the material.

The relative thermal index (RTI), where specified for the material, provides the maximum continuous operating temperature at which its electrical and mechanical properties may reduce by up to 50 % over a period of seven years.

D.2 Introductory remark

For safety reasons, components should comply either with the requirements of this document or with the safety aspects of the relevant IEC component standards.

NOTE 1 An IEC component standard is considered relevant only if the component in question clearly falls within its scope.

A component which is to be connected to a PEB, PELV or SELV circuit and also to an ELV circuit or to a part at hazardous voltage should comply with Clause D.3 to Clause D.9 for a PEB, PELV or SELV circuit.

PEB, PELV and SELV circuits should exhibit voltages safe to touch both under normal operating conditions and after a single fault, such as breakdown of a layer of basic insulation or failure of a single component.

NOTE 2 An example of such a component is a relay with different supplies connected to different elements (coils and contacts).

The manufacturer should ensure that all safety-related components meet the safety requirements of this document.

For batteries, see 7.6.2.2.

Specific safety-related components are as follows.

D.3 Transformers

Transformers should be of a type suitable for their intended application and should comply with the relevant requirements of this document, for example, clearance and creepage distance according to Annex C, solid insulation if appropriate according to 4.8 and protection against fire according to Clause 6.

D.4 Equipment primary circuit capacitors

Capacitors used in primary circuits should be of the self-healing type to avoid short circuits when these are subjected to transient voltages which can be present on the AC or DC supply.

A capacitor connected between a supply conductor and the protective conductor circuit, for EMC decoupling to earth should be Y rated complying with IEC 60384-14. For basic insulation these should be rated to withstand 2 000 V AC RMS for 1 min or 2 200 V AC RMS for 1 s. For any double insulation requirement, the rated withstand should be 3 250 V AC RMS for 1 min or 3 575 V AC RMS for 1 s.

A capacitor connected between two supply conductors should be one of the following:

- a) an X1 capacitor complying with IEC 60384-14;
- b) an X2 capacitor which passes the impulse test of IEC 60384-14, as applied to X1 capacitors, with the test voltage reduced to 2,5 kV;
- c) an X2 capacitor which passes the endurance test of IEC 60384-14, with the 220 Ω resistor short-circuited (Annex B of IEC 60384-14:2013).

D.5 Coil devices – transformers, instrument transformers and transducers, reactors, and operating coils of relays and contactors with multiple windings and/or screen

D.5.1 Coil windings

To maintain the minimum required separation distances between windings, measures which prevent the following should be implemented:

- undesirable shifting of the windings or of their turns, especially at the edge of the winding layers;
- undesirable shifting of turns or of the inner wiring, in the case of breakage near connections or of unfastening or detachment of connections.

Measures taken against undesirable shifting of windings or wires can include the following:

- a) windings with or without coil form, on different limbs of the core;
- b) windings in different chambers of the coil form; in the event that the partition walls of the chambers are merely inserted into place, sufficient coverage of the intervening joint should be ensured;
- c) intermediate layers made of stiff insulation material which extend sufficiently beyond the windings when used with flangeless windings, or which completely fill the clearance width between flanges when used with coil forms with flanges; in the latter case, the intervening joint space up to the flange should also be sufficiently covered;
- d) filling out of incompletely wound winding layers by means of insulation material;
- e) intermediate layer consisting of several thicknesses of feathered sheeting of such a width that the feathering lies flush against the flange of the coil form and thereby prevents individual edge windings from slipping through; for feathered edge tape to act as an insulation barrier between windings, insulation barrier impregnation or casting of the windings is required as per item h) below;
- f) layer-by-layer winding with insulating intermediate layers, for example, with feathered sheeting;
- g) securing of the edge windings by means of adhesive tape or other suitable means of fastening;
- h) impregnation or casting of the windings with material which hardens and completely fills out the intermediate spaces and which securely holds the edge windings; vacuum impregnation or casting is recommended, in order to extensively exclude the formation of gas bubbles (the presence of which could promote partial discharge).

Such impregnation or casting fulfils the purpose required, but only if sufficient care is taken to ensure that undesirable shifting of a winding does not occur before hardening. Production faults, mechanical action, or thermal effects can cause such undesired shifting.

Care should be taken that any clearances or creepage distances (which may develop over gaps and separating joints of the coil forms, or over intermediate layers, and which cannot be reliably eliminated by impregnation or casting) comply at least with the values stipulated in 4.9 and Annex C.

D.5.2 Insulating foil

If insulating foil is to be used for insulation, then this foil should consist of at least two layers for basic insulation purposes. For purposes of reinforced insulation, it should consist of at least three layers. Varnish or enamel insulation of the wires should not be considered as insulation with respect to another circuit or to an accessible conductive part.

D.5.3 Interposing protective screen

The protective screen between concentrically configured windings should cover the adjacent windings over the entire width and the entire extent and/or there should be adequate clearance and creepage distance between the windings. The protective screen may also consist of an appropriately designed shielding winding.

D.5.4 Safety isolation transformers

Safety isolation transformers in accordance with IEC 61558 may be employed (with observance of the restrictions of the scope of application of IEC 61558, for example, rated frequency < 500 Hz) under the condition that the double or reinforced insulation between the protectively separated circuits does not produce partial discharges which can reduce the insulation withstand.

Safety isolation transformers above 500 Hz are under consideration.

NOTE When conducting the voltage test of safety isolating transformers in accordance with IEC 61558, there is a hazardous situation that the test will damage the insulation between the input and output side as a result of the partial discharge which occurs. The stipulated partial-discharge test mentioned above serves to identify unsuitable transformers.

D.6 Electromechanical components

Electromechanical components which form an interface between different circuits (switches, all-or-nothing relays, contactors, circuit-breakers) should comply with the points below.

- a) It is especially important in cases of encapsulated electromechanical components (for example, all-or-nothing relays, see IEC 61810-1) to ensure that the unfastening or detachment of a movable part (for example, contact pieces, contact springs and the like) will not result in damage of the insulation provided for purposes of protective separation.
- b) In the case of strong electrical arcs due to external connection, the creepage distances which serve for protective separation should be configured in such a manner that they maintain their long-term insulation function. Protection can be afforded, for example, by ensuring sufficient physical separation or by encapsulation.

D.7 Semiconductor components and semiconductor configurations

Semiconductor junctions for use as protective separation of circuits are not permitted.

Semiconductor configurations, also including hybrids, for example, semiconductor contactors, electronic transformers and convertors, optical couplers, isolation amplifiers, and compact power supplies are permitted for basic insulation and reinforced insulation if they are designed and implemented to withstand the appropriate voltage tests without tracking. The insulation resistance test can be used to determine if there has been any detrimental tracking.

The energy or information transfer interfaces for protective separation should then satisfy the requirement for coil devices (according to Clause D.5) or for optical coupler elements.

Laser components should be in accordance with IEC 60825-1.

D.8 Connectors and terminal blocks

Insulation may be provided within connectors for connecting leads, or for electrical connection for sub-assemblies by omitting or not connecting contact tips or points (for example, creating space). A bent or broken-off contact tip or point should not impair the insulation to the extent that it no longer fulfils the requirements for basic insulation.

The requirements in 4.11.5 of IEC 62477-1:2022 apply for the non-interchangeability and for protection against polarity reversal of connectors.

In the case of terminal blocks for the connection of sub-assemblies and devices, additional measures are required (in addition to those for sufficient clearances and creepage distances) to effectively prevent the unintentional false connection of such equipment. These measures should be implemented by at least one of the following:

- a) a separation interval of at least the width of one terminal clamp;
- b) one terminal clamp which is not connected;
- c) one terminal clamp connected to the protective conductor;
- d) one intermediate insulating piece which extends above the terminals on the connection sides;
- e) one protective screen which extends above the terminals on the connection sides;
- f) employment of terminals of different sizes for these circuits;
- g) employment of highly obvious designation, for example, by apparent colour coding.

See also 7.2.

When breaking the connection of connectors and terminal blocks and when there is a hazardous situation through mechanical action of breaking a lead or unfastening or detaching a lead, the insulation could be damaged to the extent that the requirements for basic insulation are no longer satisfied. Effective measures should be taken to prevent such damage.

D.9 Voltage dependent resistors (VDRs)

A VDR should consider all of the following:

- a) Maximum continuous voltage:
 - at least 1,25 times the rated voltage of the equipment; or
 - at least 1,25 times the upper voltage of the rated voltage range.

NOTE The maximum continuous voltages are not limited to values specified in IEC 61051-2.

- b) Combination pulse (Table I group 1 of IEC 61051-2:2021).

For the test, a combination pulse is selected from 2.3.6 in IEC 61051-2:2021. The test consists of 10 positive pulses or 10 negative pulses, each having a shape of 1,2/50 μ s for voltage and 8/20 μ s for current.

Rated voltage under 300 V is considered to be 300 V. For working voltages of 300 V up to overvoltage category IV and 600 V up to overvoltage category III, devices complying with UL 1449 are considered to meet these requirements.

For overvoltage category IV a combination pulse 6 kV/3 kA is used except for equipment intended for connection to a system supply of 600 V, for which a combination pulse of

8 kV/4 kA is used. As an alternative to the 6 kV/3 kA test, the combination pulse test of IEC 61051-2:2021 (2.3.6, Table I group 1 and Annex A), including consideration of the rated voltage and overvoltage category, is acceptable.

In addition to the performance requirements of Table I group 1 of IEC 61051-2:2021, the VDR voltage at the manufacturer's specified current after the test should not have changed by more than 10 % when compared to the value before the test.

The body of the VDR should comply with the needle flame according to IEC 60695-11-5, with the following test severities:

- duration of application of the test flame: 10 s;
- after flame time: 5 s.

If the body of the VDR complies with V-1 class material, the needle flame test does not need to be performed.

D.10 Intentional radio transmitters

Intentional radio transmitters to comply with health and safety legislation need to ensure that the power and frequency remain within the limits for the standards with which they are compliant. The intentional transmitters are outside the scope of this document and the communication specific standards will take precedence such as IEC 62479 and IEC 62368-1 (dedicated safety).

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Annex E (normative)

External wiring terminations

E.1 General

This Annex E provides provisions for external wiring terminations of equipment in the scope of this document.

E.2 Permanently connected equipment

Permanently connected equipment shall be provided with either:

- a) a set of terminals; or
- b) a non-detachable power supply cable.

Equipment designed for permanent connection and equipment with ordinary non-detachable power supply cables shall be provided with terminals in which connection is made by means of screws (screws or nuts with lock washers are not regarded as liable to become loose, nor are wires which are mechanically secured by more than soldering alone), nuts or equally effective devices (not removable without the use of a tool), to provide mechanical security.

This applies to current transformer (CT) and voltage transformer (VT) connections in addition to those for the AC or DC supply and protective conductors. It also applies to input and output connections for which the voltage is in excess of ELV voltage levels.

Screws and nuts which clamp external power supply conductors shall have a thread conforming to international standards (for example, unified threads).

The screws and nuts shall not be used to secure components. They are, however, permitted to clamp internal conductors, provided that these are arranged in such a way that it is unlikely that they will be displaced by insertion or removal of the supply or protective conductors.

For the purpose of applying the requirements for power supply cables:

- it is assumed that two independent fixings will not become loose at the same time;
- crimped conductors shall be mechanically retained, for example, by an insulation clamp or additional fixing close to the terminal.

Conformity with Clause E.2 is checked by inspection.

E.3 Conductors

Terminals shall allow the connection of conductors having cross-sectional areas as shown in Table E.1.

Where heavier gauge conductors are used, the terminals shall be sized accordingly.

Conformity with Clause E.3 is checked by inspection and by fitting cables of the smallest and largest cross-sectional areas of the appropriate range shown in Table E.1.

Table E.1 – Range of conductor sizes to be accepted by terminals

Cable termination application	Recommended cable size mm ²
CT circuits	2,5 to 6,0
Alarm and signalling, for example, SCADA	≥ 0,5
Wired network port, for example, RS232	As recommended by the manufacturer
Other circuits, for example, VT, auxiliary, etc.	1,0 to 2,5

E.4 Terminals

Terminals shall have minimum sizes as shown in Table E.2. Stud terminals shall be provided with washers.

Table E.2 – Sizes of terminal studs or screws directly securing supply conductors

Rated current of equipment	Minimum thread diameter mm	
	Pillar or stud size	Screw size ^{a,b}
Up to and including 10 A	3,0	3,5
Over 10 A up to and including 16 A	3,5	4,0

^a Screw size refers to a terminal that clamps the conductor under the head of a screw, with or without a washer. This does not exclude the indirect securing of conductors by other means, for example, a "moving cage clamp", using smaller screw sizes.

^b If the screw size does not meet these requirements, the manufacturer shall demonstrate conformity by type testing. The resultant temperature at maximum current and at maximum ambient temperature, shall not exceed the ratings of the materials used. The terminations shall remain mechanically secure.

Terminals shall be so designed that they clamp the conductor between metal surfaces with sufficient contact pressure and without damage to the conductor.

Terminals shall be so designed or located that the conductor cannot slip out when the clamping screws or nuts are tightened.

Terminals shall be so fixed that when the means of clamping the conductor is tightened or loosened:

- a) the terminal itself does not work loose;
- b) internal wiring is not subjected to stress;
- c) creepage distances and clearances are not reduced below the values specified in Annex C.

Conformity with the requirements of Clause E.4 is checked by inspection and measurement.

For ordinary non-detachable power supply cables, each terminal shall be located in proximity to its corresponding terminal or terminals of different potential.

Conformity of non-detachable power supply cables is checked by inspection.

Annex F (informative)

Examples of battery protection

This Annex F gives typical examples of battery protection to reduce overheating or explosion risk under a single fault condition. See Figure F.1 and Figure F.2.

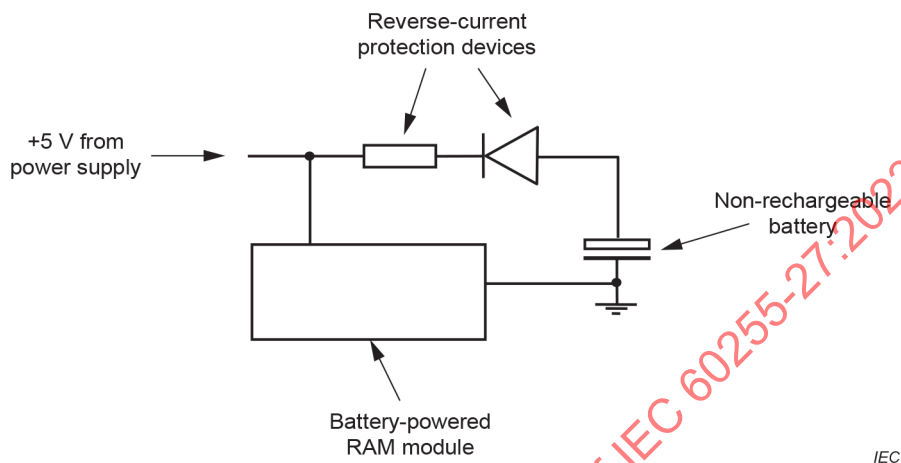
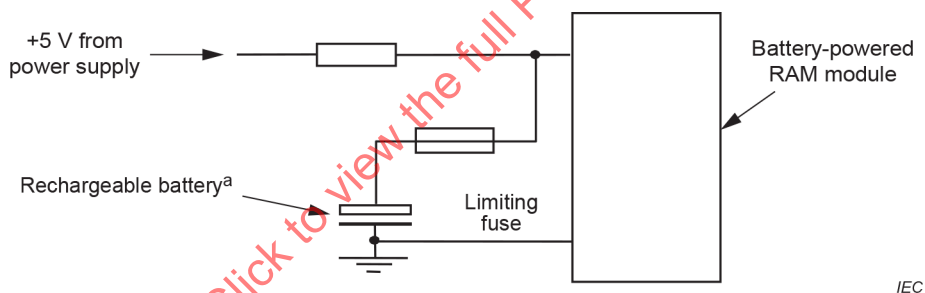


Figure F.1 – Non-rechargeable battery protection



^a Charge and discharge currents shall be limited to safe values.

Figure F.2 – Rechargeable battery protection

Annex G (informative)

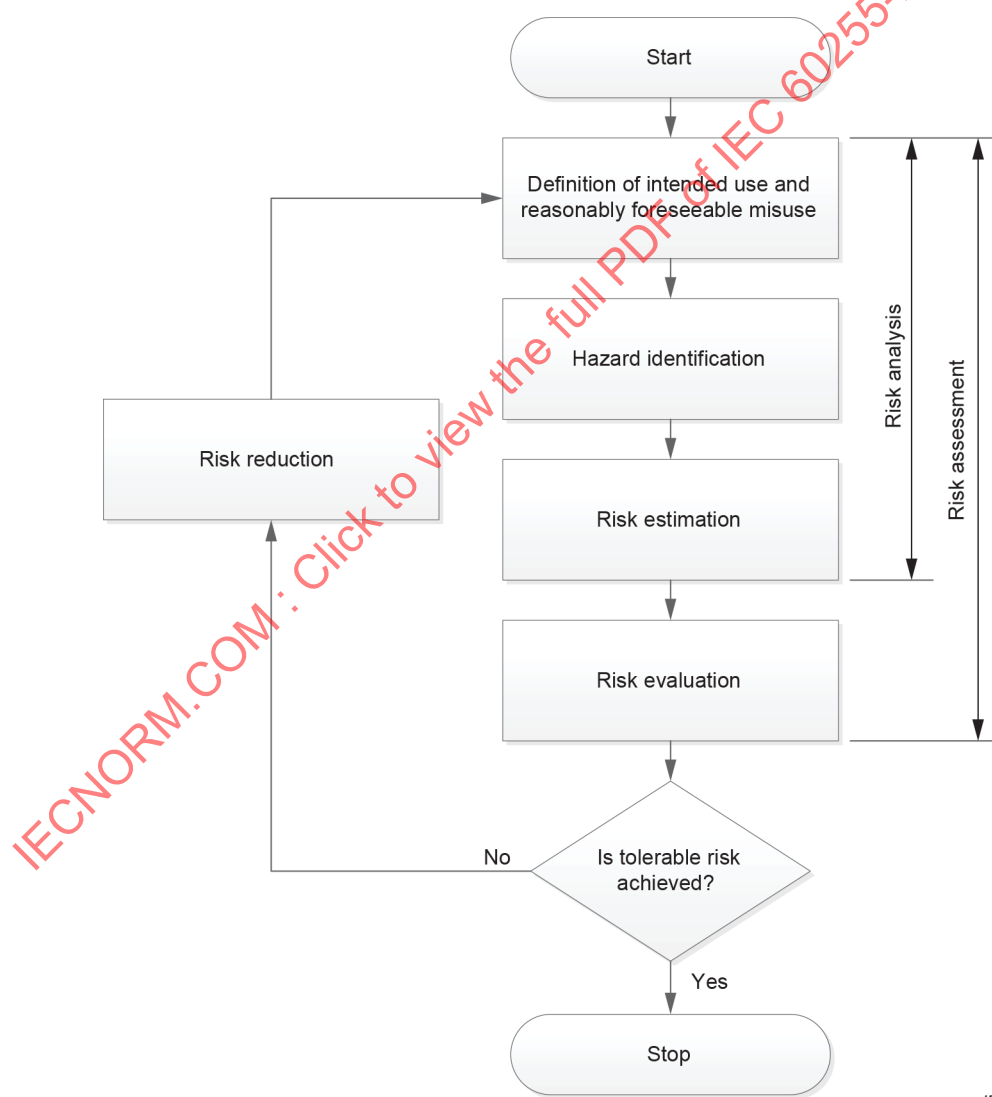
Risk assessment

G.1 General

A risk assessment process based on ISO/IEC Guide 51 and IEC 61010-1 is given below. In IEC 61508 other risk assessment procedures are contained which implement similar steps and can also be used.

G.2 Risk assessment procedure

Tolerable risk is achieved by the iterative process of risk assessment (risk analysis and risk evaluation) and risk reduction (see Figure G.1).



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Figure G.1 – Iterative process of risk assessment and risk reduction

G.3 Achieving tolerable risk

The following procedure (see Figure G.1) should be used to reduce risks to a tolerable level:

- identify the likely user group(s) for the product, process, or service;
- identify the intended use and assess the reasonably foreseeable misuse of the product, process or service;
- identify each hazard (including any hazardous situation and harmful event) arising in all stages and conditions for the use of the product, process or service, including installation, maintenance, repair, and disposal;
- estimate and evaluate the risk (see Figure G.1) to each identified user and/or contact group arising from each hazard identified;
- judge if the risk is tolerable (e.g. by comparison with similar products, processes or services);
- if the risk is not tolerable, reduce the risk until it becomes tolerable.

When reducing risks the order of priority should be as follows:

- eliminate or reduce risks as far as possible (inherently safe design and construction);
- take the necessary protection measures in relation to risks that cannot be eliminated (protection devices);
- inform users of the residual risks due to any shortcomings of the protection measures adopted, indicate whether any particular training is required, and specify any need to provide personal protective equipment (information for safety).

This procedure assumes that the user has a role to play in the risk reduction procedure by complying with the information provided by the manufacturer (see Figure G.2).

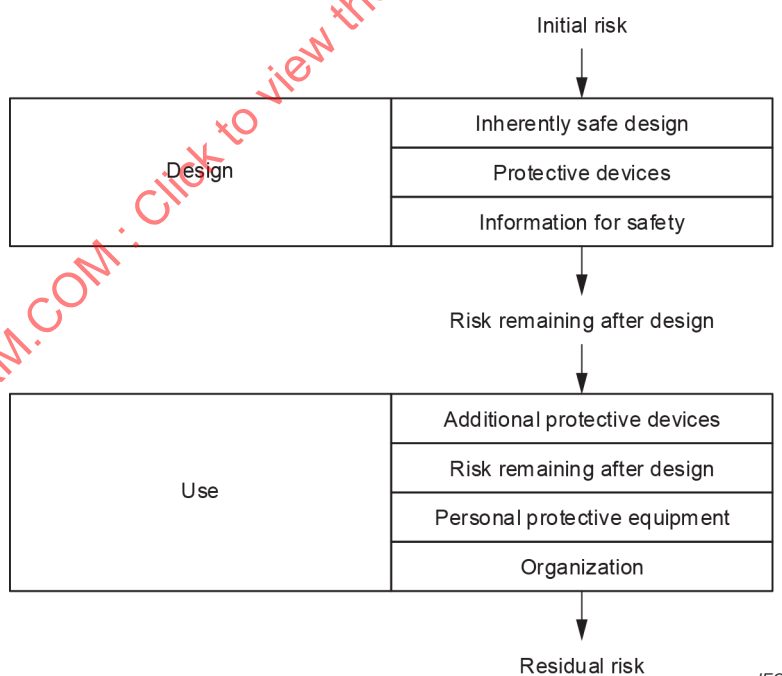


Figure G.2 – Risk reduction

The steps taken in the design procedure are shown in order of priority. The steps to be taken by the user are not in order of priority because this would depend on the application. It is emphasized that the additional protection devices, personal protective equipment and provision of information to users should not be used as substitutes for design improvements.

G.4 An application of risk assessment procedures

For hazards in the scope of this document, examples of severity of harm are given in Table G.1. Probability of harm is given in Table G.2. The risk category, which is selected based on severity and probability, is given in Table G.3.

Table G.1 – Severity of harm

Severity group	People	Equipment or facility	Environment
Catastrophic	One or more fatalities	System or facility loss	Chemical release with acute or public health impact
Severe	Disabling injury or illness	Major subsystem loss or facility damage	Chemical release with temporary environmental or public health impact
Moderate	Medical treatment or restricted work activity	Minor subsystem loss or facility damage	Chemical release triggering external reporting requirements
Minor	First aid only	Non-serious equipment or facility damage	Chemical release requiring only routine cleanup without reporting

Table G.2 – Probability of harm

Likelihood	Expected rate of occurrence
Frequent	More than five times a year
Likely	More than once per year, but not more than five times a year
Possible	More than once in five years, but not more than once a year
Rare	More than once in ten years, but not more than once in five years
Unlikely	No more than once in ten years

Table G.3 – Risk category

Risk assessment / risk category						
Severity of harm		Probability of harm				
		Frequent	Likely	Possible	Rare	Unlikely
Severity	Catastrophic	3	3	3	2	2
	Severe	3	3	2	2	1
	Moderate	3	2	1	1	1
	Minor	2	1	1	1	1
Key	Category		Description			
1	Broadly acceptable		This fulfils the requirement for tolerable risk.			
2	As low as reasonably practicable		This does not automatically fulfil the requirement for tolerable risk. If possible, these risks should be reduced further to Category 1. If not possible, then the instructions should contain a description of the risk so that the responsible body can take appropriate steps to protect the safety of operators.			
3	Intolerable		This contains risks that are not tolerable risks.			

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

RELAIS DE MESURE ET DISPOSITIFS DE PROTECTION –

Partie 27: Exigences de sécurité des produits

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L'IEC 60255-27 a été établie par le comité d'études 95 de l'IEC: Relais de mesure et dispositifs de protection. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2013. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) suppression des énoncés contradictoires;
- b) clarification du domaine d'application et ajout de l'énoncé qui précise que tous les articles de la norme constituent des exigences, et pas seulement les essais de type;

- c) alignement de la terminologie, des définitions et des exigences de documentation sur l'IEC 60255-1;
- d) alignement sur l'IEC 61010-1, par exemple pour les définitions relatives à la TAD;
- e) clarification de l'indice de protection;
- f) ajout des essais diélectriques et des essais de choc aux exigences d'essais mécaniques et d'environnement;
- g) mise à jour des exigences relatives à la résistance d'isolement pour s'aligner sur d'autres normes de sécurité des produits;
- h) suppression des essais sur prélèvement;
- i) ajout de la surcharge thermique limite de courte durée;
- j) ajout de la résistance aux contraintes mécaniques;
- k) ajout des accès de transformateurs de tension et de courant de faible puissance;
- l) mise à jour des tableaux de l'Annexe C pour correspondre aux normes de référence;
- m) ajout des résistances sensibles à la tension et des émetteurs radioélectriques à l'Annexe D;
- n) ajout de l'Annexe G pour l'évaluation des risques.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
95/516/FDIS	95/526/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC 60255, publiées sous le titre général *Relais de mesure et dispositifs de protection*, se trouve sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

INTRODUCTION

Le présent document spécifie les exigences de sécurité qui s'appliquent généralement à tous les matériels qui relèvent de son domaine d'application. Ces exigences peuvent être complétées par des normes générales de sécurité des produits et par l'IEC 60664-1.

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RELAIS DE MESURE ET DISPOSITIFS DE PROTECTION –

Partie 27: Exigences de sécurité des produits

1 Domaine d'application

La présente partie de l'IEC 60255 spécifie les exigences de sécurité des produits pour les relais de mesure et les dispositifs de protection avec une tension assignée en courant alternatif inférieure ou égale à 1 000 V ou avec une tension assignée en courant continu inférieure ou égale à 1 500 V. Au-dessus de ces limites, l'IEC 60664-1 s'applique pour déterminer les distances d'isolement, les lignes de fuite et les tensions d'essai de tenue.

Le présent document spécifie les exigences de sécurité fondamentales pour réduire le plus possible les risques d'incendie et de dangers causés par un choc électrique ou les risques de blessure de l'utilisateur et de dégradation matérielle. Le présent document spécifie uniquement les exigences de sécurité des produits; les performances fonctionnelles du matériel ne sont pas couvertes.

En revanche, le présent document couvre tous les modes qui peuvent être utilisés pour le montage et l'utilisation du dispositif dans des baies, des racks ou des panneaux. Le présent document s'applique aussi aux dispositifs auxiliaires comme les shunts, résistances série, transformateurs, panneaux de commande auxiliaires, dispositifs d'affichage, etc., qui sont utilisés conjointement avec les relais de mesure et les dispositifs de protection et sont soumis à l'essai ensemble.

Il est possible qu'il soit nécessaire que les matériels auxiliaires tels que les commutateurs réseau utilisés conjointement avec les relais de mesure et les dispositifs de protection satisfassent à des exigences de sécurité supplémentaires.

Le présent document ne s'applique pas à la mise en œuvre individuelle de matériels, de circuits, et de composants.

Le présent document s'applique aux matériels conçus pour être sûrs au moins dans les conditions d'environnement suivantes:

- installation à l'intérieur;
- altitude jusqu'à 2 000 m conformément à l'IEC 60255-1;
- plage assignée de températures ambiantes conformément à l'IEC 60255-1;
- humidité relative extérieure maximale conformément à l'IEC 60255-1;
- plage de fonctionnement de la tension d'alimentation auxiliaire conformément à l'IEC 60255-1;
- catégorie de surtension applicable;
- degré de pollution applicable de l'environnement prévu (degré de pollution 2 dans la plupart des cas).

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60085, *Isolation électrique – Évaluation et désignation thermiques*

IEC 60127-1, *Miniature fuses – Part 1: Definitions for miniature fuses and general requirements for miniature fuse-links* (disponible en anglais seulement)

IEC 60255-1, *Relais de mesure et dispositifs de protection – Partie 1: Exigences communes*

IEC 60255-26, *Relais de mesure et dispositifs de protection – Partie 26: Exigences de compatibilité électromagnétique*

IEC 60352-1, *Connexions sans soudure – Partie 1: Connexions enroulées – Règles générales, méthodes d'essai et guide pratique*

IEC 60352-2, *Connexions sans soudure – Partie 2: Connexions serties – Exigences générales, méthodes d'essai et guide pratique*

IEC 60417, *Symboles graphiques utilisables sur le matériel*. Disponible à l'adresse: <http://www.graphical-symbols.info/equipment>

IEC 60529:1989, *Degrés de protection procurés par les enveloppes (code IP)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60664-1:2020, *Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

IEC 60664-3, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 3: Utilisation de revêtement, d'empotage ou de moulage pour la protection contre la pollution*

IEC TS 60695-2-20, *Fire hazard testing – Part 2-20: Glowing/hot-wire based test methods – Hot-wire coil test method – Apparatus, test method and guidance* (disponible en anglais seulement)

IEC 60695-11-10, *Essais relatifs aux risques du feu – Partie 11-10: Flamme d'essai – Méthodes d'essai horizontale et verticale à la flamme de 50 W*

IEC 60825-1, *Sécurité des appareils à laser – Partie 1: Classification des matériels et exigences*

IEC 60990:2016, *Méthodes de mesure du courant de contact et du courant dans le conducteur de protection*

IEC 61010-1:2010, *Règles de sécurité pour appareils électriques de mesurage, de régulation et de laboratoire – Partie 1: Exigences générales*

IEC 61010-1:2010/AMD1:2016

IEC 61032, *Protection des personnes et des matériels par les enveloppes – Calibres d'essai pour la vérification*

IEC 61051-2:2021, *Varistances utilisées dans les équipements électroniques – Partie 2: Spécification intermédiaire pour varistances pour limitations de surtensions transitoires*

IEC 61180, *Techniques des essais à haute tension pour matériel à basse tension – Définitions, exigences relatives aux essais, matériel d'essai*

IEC 61869-6, *Transformateurs de mesure – Partie 6: Exigences générales supplémentaires concernant les transformateurs de mesure de faible puissance*

IEC 61869-10, *Transformateurs de mesure – Partie 10: Exigences supplémentaires concernant les transformateurs de courant passifs de faible puissance*

IEC 61869-11, *Transformateurs de mesure – Partie 11: Exigences supplémentaires pour les transformateurs de tension passifs de faible puissance*

IEC 62151, *Sécurité des matériels reliés électriquement à un réseau de télécommunications*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <https://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <https://www.iso.org/obp>

3.1

partie conductrice accessible

partie conductrice d'un matériel électrique qui peut être touchée en utilisation normale

3.2

partie accessible

partie qui peut être touchée en utilisation normale au moyen d'un doigt d'épreuve rigide ou articulé normalisé, comme cela est spécifié en 6.2 de l'IEC 61010-1:2010 et de l'IEC 61010-1:2010/AMD1:2016

Note 1 à l'article: Les circuits destinés à être connectés à un circuit accessible externe sont considérés comme des parties conductrices accessibles (accès de réseau câblé, par exemple).

3.3

circuit adjacent

circuit indépendant

circuit électrique qui est séparé du circuit à l'étude par l'isolation applicable

3.4

température ambiante

température de l'air ambiant

température déterminée dans des conditions prescrites de l'air qui entoure la totalité du matériel

Note 1 à l'article: Pour les matériels installés à l'intérieur d'une enveloppe, c'est la température de l'air à l'extérieur de l'enveloppe.

Note 2 à l'article: La température ambiante est mesurée à mi-distance des matériels voisins, mais pas à plus de 300 mm de l'enveloppe du matériel, à mi-hauteur du matériel, protégée du rayonnement thermique direct du matériel.

[SOURCE: IEC 60050-441:1984, 441-11-13, modifié – Le terme privilégié "température ambiante" a été ajouté. Dans la définition et la Note 1 à l'article, les termes "appareil de connexion" et "fusible" ont été conjointement remplacés par "matériel". La note 2 à l'article a été ajoutée.]

3.5

barrière

barrière de protection électrique

partie assurant la protection, dans toute direction habituelle d'accès, contre tout contact direct et qui est solidement maintenue en place de manière à ne pouvoir être enlevée qu'à l'aide d'un outil

[SOURCE: IEC 60050-826:2004, 826-12-23, modifié – Le terme privilégié "barrière" a été ajouté. A la fin de la définition, les mots "et qui est solidement maintenue en place de manière à ne pouvoir être enlevée qu'à l'aide d'un outil" ont été ajoutés.]

3.6

isolation principale

isolation des parties actives dangereuses pour procurer la protection principale

[SOURCE: IEC 60050-826:2004, 826-12-14, modifié – Dans la définition, "qui assure" a été remplacé par "pour procurer" et la Note à l'article a été supprimée.]

3.7

protection principale

protection contre les chocs électriques dans des conditions normales

[SOURCE: IEC 60050-195:2021, 195-06-01]

3.8

surface de délimitation

surface extérieure de l'enveloppe du matériel

3.9

baie

enveloppe auto-stable et autoporteuse prévue pour contenir le matériel électrique et/ou électronique

Note 1 à l'article: Une baie est habituellement équipée de portes et/ou de panneaux latéraux, qui peuvent ou non être amovibles.

[SOURCE: IEC 60050-581:2008, 581-25-02]

3.10

distance d'isolement

distance la plus courte, mesurée dans l'air, entre deux parties conductrices, ou entre une partie conductrice et la surface de délimitation extérieure du matériel, qu'elle soit conductrice ou non

3.11**indice de résistance au cheminement****IRC**

valeur numérique de la tension maximale, exprimée en volts, qu'un matériau peut supporter sans cheminement et sans apparition de flammes persistantes dans des conditions d'essai spécifiées

[SOURCE: IEC 60050-212:2010, 212-11-59]

3.12**ligne de fuite**

distance la plus courte, le long de la surface d'un isolant solide, entre deux parties conductrices, ou entre une partie conductrice et la surface de délimitation (partie accessible) du matériel, mesurée le long de la surface isolante

[SOURCE: IEC 60050-151:2001, 151-15-50, modifié – Les mots ", ou entre une partie conductrice et la surface de délimitation (partie accessible) du matériel, mesurée le long de la surface isolante" ont été ajoutés.]

3.13**contact direct**

contact électrique de personnes avec des parties actives

[SOURCE: IEC 60050-826:2004, 826-12-03, modifié – Dans la définition, les mots "ou d'animaux" ont été supprimés.]

3.14**double isolation**

isolation comprenant à la fois une isolation principale et une isolation supplémentaire

Note 1 à l'article: L'isolation principale et supplémentaire sont distinctes, chacune conçue pour la protection principale contre les chocs électriques.

[SOURCE: IEC 60050-195:2021, 195-06-08, modifié – La note à l'article a été ajoutée.]

3.15**enveloppe**

enceinte assurant le type et le degré de protection approprié pour l'application prévue

Note 1 à l'article: Les enveloppes peuvent procurer la protection contre la propagation du feu (voir Article 7).

[SOURCE: IEC 60050-151:2001, 151-13-08, modifié – La Note 1 à l'article a été ajoutée.]

3.16**très basse tension****TBT**

tension ne dépassant pas la valeur maximale de la tension de contact présumée qu'il est acceptable de maintenir indéfiniment dans les conditions d'influences externes spécifiées

Note 1 à l'article: Pour les besoins du présent document, les valeurs de TBT sont spécifiées en 4.3.3.2.

VOIR: Tableau A.1

[SOURCE: IEC 60050-195:2021, 195-05-24, modifié – La note à l'article a été ajoutée.]

3.17

enveloppe ignifuge

enveloppe assurant la protection contre la propagation du feu depuis l'intérieur de l'enveloppe vers l'extérieur de l'enveloppe

[SOURCE: IEC 60050-903:2014, 903-04-10, modifié – La Note 1 à l'article a été supprimée.]

3.18

circuit avec mise à la terre fonctionnelle

circuit qui peut comprendre des pistes de PCB, des câbles, des composants et des liaisons équipotentielle, relié à la terre à des fins autres que la sécurité électrique

Note 1 à l'article: Un écran et un point de référence pour les mesures constituent des fins autres que la sécurité électrique.

3.19

isolation fonctionnelle

isolation entre parties conductrices, nécessaire pour le bon fonctionnement du matériel

[SOURCE: IEC 60050-195:2021, 195-02-41]

3.20

niveau d'énergie dangereux

niveau de puissance disponible de 240 VA ou plus d'une durée de 60 s ou plus, ou niveau d'énergie stocké de 20 J ou plus (par exemple, un ou plusieurs condensateurs), à un potentiel de 2 V ou plus

3.21

partie active dangereuse

partie sous tension dangereuse

partie active qui peut provoquer, dans certaines conditions, un choc électrique nuisible

[SOURCE: IEC 60050-826:2004, 826-12-13]

3.22

tension active dangereuse

TAD

tension d'utilisation normale qui dépasse les niveaux de TBT

Note 1 à l'article: Pour les besoins du présent document, les valeurs de TBT sont spécifiées en 4.3.3.2.

3.23

partie à haute intégrité

composant à haute intégrité

partie ou composant dont la spécification ou la qualification est nettement supérieure à l'application, de sorte que le risque de défaillance est minime

3.24

partie active

partie sous tension

partie conductrice destinée à être sous tension dans des conditions normales de fonctionnement, y compris le conducteur de neutre

[SOURCE: IEC 60050-195:2021, 195-02-19, modifié – La dernière partie de la définition, "et le conducteur de point milieu, à l'exception toutefois du conducteur PEN, du conducteur PEM et du conducteur PEL", a été supprimée.]

3.25**transformateur de mesure de faible puissance****LPIT**

dispositif composé d'au moins un transformateur de courant ou de tension qui peut être raccordé à des systèmes de transmission et à des convertisseurs secondaires, destinés à transmettre un signal de sortie analogique ou numérique de faible puissance aux appareils de mesure, aux compteurs, aux dispositifs de protection ou de commande ou à des appareils similaires

EXEMPLE Un dispositif composé de trois capteurs de courant, de trois capteurs de tension connectés à un concentrateur qui délivre une sortie numérique est considéré comme un LPIT.

Note 1 à l'article: Les LPIT sont souvent appelés transformateurs de mesure non conventionnels (NCIT, *Non-Conventional Instrument Transformers*).

Note 2 à l'article: La puissance de sortie générée par ces dispositifs est généralement inférieure ou égale à 1 VA.

Note 3 à l'article: L'abréviation "LPIT" est dérivée du terme anglais développé correspondant "low-power instrument transformer".

[SOURCE: IEC 61869-6:2016, 3.1.601]

3.26**transformateur de courant de faible puissance****LPCT**

transformateur de mesure de faible puissance qui permet de mesurer le courant

Note 1 à l'article: L'abréviation "LPCT" est dérivée du terme anglais développé correspondant "low-power current transformer".

[SOURCE: IEC 61869-6:2016, 3.1.602]

3.27**transformateur de tension de faible puissance****LPVT**

transformateur de mesure de faible puissance qui permet de mesurer la tension

Note 1 à l'article: L'abréviation "LPVT" est dérivée du terme anglais développé correspondant "low-power voltage transformer".

[SOURCE: IEC 61869-6:2016, 3.1.603]

3.28**utilisation de maintenance**

état d'un matériel lorsque sa maintenance est assurée par un personnel dûment formé et que ses capots et dispositifs de protection amovibles à l'aide d'un outil ont été retirés

3.29**circuit non primaire**

circuit isolé électriquement de l'alimentation en courant alternatif ou en courant continu, ainsi que des transformateurs de tension et des transformateurs de courant externes

3.30**utilisation normale**

état d'un matériel lorsqu'il est installé et fonctionne selon l'utilisation prévue, et que ses capots et dispositifs de protection amovibles sont en place

3.31**surchauffe**

fonctionnement à un niveau tel que la limite thermique est dépassée

3.32

catégorie de surtension

chiffre définissant une condition de surtension transitoire

Note 1 à l'article: Les catégories de surtension I, II, III et IV sont utilisées. Voir l'IEC 60664-1.

[SOURCE: IEC 60050-426:2020, 426-04-48]

3.33

matériel de protection de classe I

matériel qui possède une isolation principale et une liaison de protection comme mesure de protection contre les chocs électriques, de telle sorte que les parties conductrices de l'extérieur de l'enveloppe ne puissent pas devenir actives (dans le cas d'une défaillance de l'isolation principale)

3.34

matériel de protection de classe II

matériel qui possède

- une isolation principale comme mesure de protection principale contre les chocs électriques et une isolation supplémentaire comme mesure de protection en cas de défaut; ou
- une protection principale et une protection en cas de défaut procurées par une double isolation ou une isolation renforcée

Note 1 à l'article: Il convient qu'il n'y ait pas de possibilité de raccorder un conducteur de protection et de ne pas compter sur les conditions d'installation pour assurer la sécurité. Il est cependant possible de relier un conducteur de terre à un matériel de protection de classe II pour des raisons fonctionnelles (CEM, par exemple).

3.35

matériel de protection de classe III

matériels, ou parties de matériels, dans lesquels la protection contre les chocs électriques s'appuie sur l'alimentation par des circuits TBTS ou TBTP et dans lesquels aucune tension dangereuse n'est générée

3.36

pollution

tout apport de matériau étranger solide, liquide ou gazeux qui peut entraîner une réduction de la rigidité diélectrique ou de la résistivité de surface de l'isolation

[SOURCE: IEC 60050-442:1998, 442-01-28, modifié – Dans la définition, l'adjectif "permanente" a été supprimé, de même que la note.]

3.37

degré de pollution

nombre qui caractérise la pollution attendue des conditions ambiantes à proximité immédiate des distances d'isolement et des lignes de fuite à l'étude, comme cela est indiqué dans l'IEC 60664-1

3.38

circuit primaire

circuit connecté électriquement à l'entrée d'alimentation en courant alternatif ou en courant continu, ainsi qu'aux transformateurs de tension et aux transformateurs de courant externes

3.39

liaison de protection

liaison électrique à des parties conductrices accessibles ou à un écran de protection réalisée afin de fournir la continuité électrique avec la terre au moyen d'un conducteur de protection externe, lui-même mis à la terre de façon sûre

3.40**résistance de liaison de protection**

résistance entre la borne du conducteur de protection et une partie conductrice qui doit être raccordée au conducteur de protection

3.41**conducteur de protection**

conducteur prévu à des fins de sécurité électrique

[SOURCE: IEC 60050-195:2021, 195-02-09]

3.42**mise à la terre de protection**

action de mettre à la terre à des fins de protection contre les chocs électriques

[SOURCE: IEC 60050-195:2021, 195-01-11, modifié – Le terme "sécurité électrique" a été remplacé par "protection contre les chocs électriques".]

3.43**circuit avec protection par liaison équipotentielle****circuit PEB**

circuit avec un chemin de faible impédance entre les parties conductrices exposées et les parties conductrices étrangères, afin d'assurer un potentiel égal sur l'ensemble de celui-ci et d'empêcher ainsi la survenue d'une différence de potentiel dangereuse entre ces parties en cas de défaut

Note 1 à l'article: Voir Tableau A.1.

Note 2 à l'article: L'abréviation "PEB" est dérivée du terme anglais développé correspondant "protective equipotential bonding".

3.44**circuit à très basse tension de protection****circuit TBTP**

circuit dans lequel la tension ne peut pas dépasser la valeur de la très basse tension en conditions normales et en conditions de premier défaut (à l'exception des défauts de terre dans d'autres circuits électriques)

Note 1 à l'article: Voir Tableau A.1.

3.45**impédance de protection**

impédance connectée entre parties actives et parties conductrices accessibles, de valeur telle que le courant, en utilisation normale et dans des conditions possibles de panne du matériel, soit limité à une valeur de sécurité, et qui est construite de façon telle que sa fiabilité soit maintenue au cours de la durée de vie du matériel

[SOURCE: IEC 60050-442:1998, 442-04-24, modifié – Dans la définition, le terme "masse" a été remplacé par "parties conductrices accessibles", et les mots "de l'interrupteur électronique" ont été remplacés par "du matériel".]

3.46**protection par écran**

séparation de circuits électriques et/ou de conducteurs par rapport aux parties actives dangereuses par un écran de protection électrique relié à la terre de protection

[SOURCE: IEC 60050-195:2021, 195-06-18, modifié – Dans la définition, les mots "au réseau équipotentiel de protection et destiné à fournir une protection contre les chocs électriques" ont été remplacés par "à la terre de protection".]

3.47

séparation de protection

séparation entre deux circuits électriques au moyen d'une protection principale et d'une protection en cas de défaut

[SOURCE: IEC 60050-195:2021, 195-06-19]

3.48

tension de choc assignée

valeur de la tension de choc assignée par le fabricant au matériel ou à une partie du matériel, qui caractérise la capacité spécifiée de tenue de son isolation aux surtensions transitoires et à laquelle se réfèrent les distances d'isolement

3.49

tension d'isolement assignée

TIA

valeur de tension assignée par le fabricant au matériel ou à une partie du matériel, qui caractérise la capacité de tenue spécifiée (à long terme) de son isolation et à laquelle se réfèrent les essais de tension diélectrique et les lignes de fuite

Note 1 à l'article: La tension d'isolement assignée n'est pas nécessairement égale à la tension assignée du matériel, qui est principalement liée aux performances fonctionnelles.

3.50

tension assignée

valeur de la tension, fixée par le fabricant dans les conditions de fonctionnement normal d'un composant, d'un dispositif ou d'un matériel

Note 1 à l'article: Les matériels peuvent avoir plusieurs valeurs ou une plage de tensions assignées.

[SOURCE: IEC 60050-442:2014, 442-09-10, modifié – Dans la définition, le terme "valeur assignée" a été remplacé par "valeur", les mots "à un composant, à un dispositif ou à un matériel" ont été remplacés par "dans les conditions de fonctionnement normal d'un composant, d'un dispositif ou d'un matériel", et à la fin de la définition, les mots "et à laquelle on se réfère pour le fonctionnement et pour les caractéristiques fonctionnelles" ont été supprimés, de même que la Note 2 à l'article.]

3.51

isolation renforcée

isolation assurant un degré de protection contre les chocs électriques équivalant à celui d'une double isolation

Note 1 à l'article: L'isolation renforcée peut comporter plusieurs couches qui ne peuvent pas être soumises aux essais séparément en tant qu'isolation principale ou isolation supplémentaire.

[SOURCE: IEC 60050-195:2021, 195-06-09]

3.52

zone d'accès limité

zone uniquement accessible aux utilisateurs munis de l'autorisation adéquate et avertis des dangers de sécurité

[SOURCE: IEC 60050-195:2021, 195-04-04, modifié – Dans la définition, les mots "aux personnes qualifiées en électricité et aux personnes averties en électricité" ont été remplacés par "aux utilisateurs" et les mots "et avertis des dangers de sécurité" ont été ajoutés.]

3.53**essai individuel de série**

essai de conformité effectué sur chaque matériel en cours ou en fin de fabrication

Note 1 à l'article: Les matériels comprennent des produits complets et des pièces détachées.

[SOURCE: IEC 60050-151:2001, 151-16-17, modifié – Dans la définition, le terme "entité" a été remplacé par "matériel" et la Note 1 à l'article a été ajoutée.]

3.54**composant essentiel pour la sécurité**

composant fiable au niveau de l'intégrité de son isolation électrique, de sa résistance mécanique, et de ses propriétés thermiques ou de sa résistance au feu en fonctionnement normal et en conditions de premier défaut, utilisé pour éviter tout danger de sécurité

3.55**circuit à très basse tension de sécurité****circuit à très basse tension séparée****circuit TBTS**

circuit dans lequel la tension ne peut pas dépasser la valeur de la très basse tension en conditions normales et en conditions de premier défaut (y compris les défauts de terre dans d'autres circuits électriques)

3.56**écran**

partie active qui enveloppe ou sépare les circuits électriques et/ou les conducteurs

Note 1 à l'article: Voir Tableau A.1.

3.57**condition de premier défaut**

condition dans laquelle il existe un défaut d'une protection simple (mais pas d'une protection renforcée) d'un composant ou d'un dispositif unique

Note 1 à l'article: Si une condition de premier défaut engendre une ou plusieurs autres conditions de défaut, toutes sont considérées comme une seule condition de premier défaut.

[SOURCE: IEC 60050-903:2013, 903-01-15]

3.58**isolation solide**

matériau qui procure une isolation électrique entre deux surfaces opposées et non le long d'une surface extérieure

3.59**isolation supplémentaire**

isolation indépendante prévue, en plus de l'isolation principale, pour procurer la protection contre les chocs électriques en cas de défaut de l'isolation principale

[SOURCE: IEC 60050-195:2021, 195-06-07, modifié – Les mots "en tant que protection en cas de défaut" ont été remplacés par "pour procurer la protection contre les chocs électriques en cas de défaut de l'isolation principale".]

3.60

cheminement

formation progressive de chemins conducteurs à la surface ou dans un isolant solide, sous l'effet combiné des contraintes électriques et de la contamination électrolytique de cette surface

Note 1 à l'article: Le cheminement est causé habituellement par une contamination superficielle.

[SOURCE: IEC 60050-212:2010, 212-11-56]

3.61

essai de type

essai effectué sur un ou plusieurs dispositifs réalisés selon une conception donnée, afin de vérifier si ces dispositifs satisfont aux exigences de la norme concernée

[SOURCE: IEC 60050-851:2008, 851-12-05]

3.62

utilisateur

personne qui possède la formation et l'expérience appropriées nécessaires pour connaître les dangers auxquels il est exposé pendant l'accès au matériel dans une zone d'accès limité et pour connaître les mesures pour réduire le plus possible les situations dangereuses pour lui-même et pour les autres personnes

3.63

accès de réseau câblé

accès destiné à la connexion des transferts vocaux, de données et de signalisation prévus pour interconnecter des systèmes largement dispersés par connexion directe à un réseau de communication avec un seul ou plusieurs utilisateurs

Note 1 à l'article: Les réseaux CATV, RTPC, RNIS, xDSL, LAN et analogues constituent des exemples.

Note 2 à l'article: Ces accès peuvent prendre en charge des câbles blindés ou non blindés et peuvent également assurer l'alimentation en courant alternatif ou en courant continu (PoE, par exemple) lorsque cela fait partie intégrante de la spécification de télécommunication.

Note 3 à l'article: Un accès généralement prévu pour relier les composants d'un système en essai (par exemple EIA-232, IEEE Std 1284 (imprimante parallèle), bus universel en série (USB), IEEE Std 1394 ("FireWire"), etc.) et utilisé conformément aux spécifications fonctionnelles applicables (concernant par exemple la longueur maximale du câble qui y est connecté) n'est pas considéré comme étant un accès de réseau câblé.

Note 4 à l'article: Les interfaces par fibre optique sont considérées comme un accès de réseau câblé. Pour obtenir une dissipation de puissance maximale, il est important que les accès par fibre optique soient actifs quand cela est exigé pendant l'évaluation de la sécurité (lors des essais d'échauffement, etc.).

3.64

tenue

aptitude du matériel à ne pas être endommagé lorsque les conditions d'environnement ou d'essai imposées sont appliquées (tension de choc, par exemple)

3.65

tension de service

valeur efficace la plus élevée de la tension en courant alternatif ou en courant continu à travers tout isolant particulier, pouvant se produire lorsque le matériel est alimenté à la tension assignée

Note 1 à l'article: Les transitoires ne sont pas pris en compte.

Note 2 à l'article: Les conditions de circuit ouvert et les conditions de fonctionnement normal sont prises en compte.

[SOURCE: IEC 60050-581:2008, 581-21-19, modifiée – Les Notes 1 et 2 à l'article ont été ajoutées.]

4 Protection contre les chocs électriques

4.1 Protection contre les contacts avec des parties actives dangereuses

4.1.1 Généralités

La protection contre le contact direct avec des parties actives dangereuses doit être procurée par une isolation adéquate, l'enveloppe du matériel ou une barrière. L'accès au matériel durant l'installation, l'utilisation de maintenance, l'utilisation normale et la mise hors service doit être limité aux utilisateurs formés aux procédures de travail nécessaires pour assurer la sécurité.

Les essais des composants et du matériel en ce qui concerne la protection contre les chocs électriques doivent être réalisés en tant qu'essais de type et essais individuels de série, définis à l'Article 9.

Les parties conductrices accessibles non reliées à la terre qui peuvent devenir dangereuses en condition de premier défaut doivent satisfaire aux exigences énoncées du 4.1 au 4.10.

4.1.2 Isolation

Toute partie conductrice qui n'est pas séparée des parties actives dangereuses par au moins une isolation principale doit être considérée comme une partie active. Les exigences d'isolation doivent être déterminées après prise en considération des facteurs d'influence suivants:

- tension d'isolement assignée du circuit à l'étude (voir C.1.3);
- catégorie de surtension (voir Annexe B et Annexe C);
- degré de pollution (voir Annexe C);
- niveau d'isolation, par exemple TBT, TBTS, TBTP ou PEB (voir Annexe A).

4.1.3 Barrières et enveloppe du matériel

La protection de l'enveloppe exigée par le produit dépend de la face et du niveau d'accès. Les exigences minimales pour l'enveloppe du matériel sont décrites dans le Tableau 1.

Tableau 1 – Exigences de protection contre les chocs électriques pour l'enveloppe du matériel

Face	Code IP (IEC 60529:1989, IEC 60529:1989/AMD1:1999, IEC 60529:1989/AMD2:2013)	Exigences
Panneau avant, côtés	IP2X ou IPXXB	Les parties actives dangereuses doivent se trouver à l'intérieur de l'enveloppe du matériel ou derrière des barrières de sorte qu'elles ne soient pas accessibles en utilisation normale. Si un capot peut être retiré sans l'aide d'un outil, le symbole d'avertissement 12 du Tableau 12 doit être visible.
Connexion(s) du panneau avant	IP2X	Les connexions du panneau avant et le câblage des bornes, qui sont à TBT, doivent être accessibles en utilisation normale.
Dessus	IP4X	Les surfaces supérieures des barrières accessibles en utilisation normale doivent procurer un indice de protection contre les chutes d'objets, les câbles détachés, les rondelles desserrées, etc. Ces barrières doivent présenter une résistance mécanique, une stabilité et une durabilité suffisantes pour maintenir le degré de protection spécifié.
Dessous	IP4X	Les surfaces inférieures des barrières accessibles en utilisation normale doivent procurer un indice de protection contre les câbles détachés, etc. Ces barrières doivent présenter une résistance mécanique, une stabilité et une durabilité suffisantes pour maintenir le degré de protection spécifié.
Arrière	IP2X	Les parties actives dangereuses doivent se trouver à l'intérieur de l'enveloppe du matériel ou derrière des barrières de sorte qu'elles ne soient pas accessibles en utilisation normale.
Connexion(s) du panneau arrière	IP1X	Le panneau de connexion arrière et le câblage des bornes en utilisation normale doivent se situer dans une zone d'accès restreint et doivent être d'indice IP1X ou supérieur.
Coins	-	Le coin doit avoir l'indice IP le plus élevé des côtés adjacents.

D'autres exigences applicables aux parties accessibles sont décrites en 4.3.2.

La conformité au 4.1.3 est vérifiée en appliquant les exigences sur les degrés de sécurité de IEC 60529:1989, de l'IEC 60529:1989/AMD1:1999 et de l'IEC 60529:1989/AMD2:2013.

4.1.4 Connexions de sortie actives dangereuses qui utilisent des fils multibrins

L'extrémité d'un fil multibrin ne doit pas être consolidée par une soudure tendre aux endroits où le fil est sujet à une pression de contact, à moins que la méthode de serrage ne soit conçue pour réduire l'éventualité d'un mauvais contact dû au fluage de la brasure. Les bornes à ressort qui compensent le fluage sont considérées comme conformes à cette exigence. Le fait d'empêcher la rotation des vis de serrage n'est pas considéré comme adéquat.

Les bornes doivent être situées, protégées ou isolées de telle façon que si le brin d'un câble souple se libère quand le câble est installé, il n'y ait pas de risque de contact accidentel entre ce brin et:

- des parties conductrices accessibles; ou
- des parties conductrices non mises à la terre, séparées des parties conductrices accessibles par une isolation supplémentaire uniquement.

Un brin libre d'une longueur de 8 mm est normalement utilisé pour évaluer ce risque.

Si le fabricant détermine qu'il existe un risque, une recommandation doit être fournie dans la documentation et le symbole d'avertissement 14 du Tableau 12 doit être marqué sur le matériel. Ce risque peut être éliminé, par exemple en utilisant une borne à sertir isolée ou un câble à un seul brin.

La conformité au 4.1.4 est vérifiée par examen.

4.2 Impédance de protection

Une impédance de protection doit limiter le courant ou la tension aux niveaux indiqués en 4.3.3.2 en utilisation normale et en 4.10.4.1.2 en condition de premier défaut.

L'isolation entre les terminaisons de l'impédance de protection doit satisfaire aux exigences d'une double isolation ou d'une isolation renforcée.

Une impédance de protection doit être constituée d'un ou de plusieurs des éléments suivants:

- a) un composant unique approprié qui doit être construit, choisi et soumis à l'essai de façon à assurer la sécurité et la fiabilité de la protection contre les chocs électriques. En particulier, le composant doit être:
 - 1) assigné à hauteur de deux fois la tension de service maximale;
 - 2) s'il s'agit d'une résistance, assigné à hauteur de deux fois la dissipation de puissance pour la tension de service maximale;
- b) une combinaison de composants, par exemple deux condensateurs de type Y en série, chacun étant dimensionné pour la tension de service totale aux bornes de la paire. Chaque condensateur doit avoir la même valeur de capacité assignée et une tenue en tension d'au moins 2 000 V en valeur efficace pendant 1 min. Cela procure la protection principale contre les chocs électriques en condition de premier défaut.

La conformité à une impédance de protection peut être démontrée par application de la tension appropriée d'essai pour la double isolation ou l'isolation renforcée comme cela est indiqué du Tableau C.8 au Tableau C.11 pour une altitude de site d'essai inférieure ou égale à 2 000 m. Pour les altitudes de site d'essai supérieures à 2 000 m, il convient d'adapter la tension d'essai conformément au Tableau C.12.

Les composants, câbles et connexions doivent avoir une valeur assignée conforme aux exigences tant en utilisation normale qu'en conditions de premier défaut appropriées. Il est admis qu'une double isolation ou qu'une isolation renforcée soit shuntée par des composants qui satisfont à l'exigence d'impédance de protection. La conformité des composants au 4.2 et toute isolation principale associée doivent être vérifiées après une évaluation ou un essai de condition de premier défaut, ou conformément au 9.6.5.5. Toute isolation principale associée doit être vérifiée par évaluation, mesurage ou essai, conformément à l'Annexe C.

4.3 Parties accessibles

4.3.1 Généralités

À moins que cela ne soit évident, la détermination de l'accessibilité d'une partie lors d'une utilisation normale doit être réalisée comme cela est indiqué ci-dessous et en 4.3.2.

Les circuits destinés à être connectés à un circuit accessible externe doivent être considérés comme des parties conductrices accessibles (accès de réseau câblé, par exemple).

Des doigts d'épreuve appropriés, comme cela est indiqué en 4.3.2.2, doivent être appliqués sans force, à moins qu'une force ne soit spécifiée. Les parties sont considérées comme étant accessibles si elles peuvent être touchées avec un doigt ou une aiguille, ou si leur capot ne constitue pas une protection adéquate lorsqu'il est touché lors d'une utilisation normale (voir ci-dessous).

Lorsque des parties conductrices accessibles ou des circuits sont séparés d'autres parties par une double isolation ou par une isolation renforcée shuntée par des composants conformément au 4.2, les parties accessibles ou les circuits doivent être conformes aux limites de courant du 4.3.3.2 en utilisation normale et du 4.10.4.1.2 en condition de premier défaut. Ces exigences doivent s'appliquer après les essais de tension diélectrique.

Pour les parties actives dangereuses, une partie est considérée comme étant accessible si le doigt ou l'aiguille d'épreuve atteint un point plus proche de la partie active dangereuse que la distance d'isolement applicable pour une isolation principale à la tension de choc assignée déterminée à partir de l'IEC 60664-1.

Pour le matériel qui accepte des modules enfichables, les parties sont considérées comme étant accessibles si elles peuvent être touchées avec le doigt d'épreuve articulé (voir 4.3.2.2) jusqu'à une profondeur de 180 mm à partir du point d'ouverture du matériel.

Les matériaux qui peuvent facilement être endommagés ne sont pas considérés comme fournissant une isolation adéquate (par exemple la laque, l'émail, les couches d'oxyde ou anodiques). Les matériaux hygroscopiques non imprégnés tels que le papier, les fibres et les matériaux fibreux ne sont pas non plus considérés comme fournissant une isolation adéquate.

Une partie métallique accessible est considérée comme étant conductrice si sa surface est dénudée ou est couverte par une couche isolante qui n'est pas conforme aux exigences d'une isolation principale.

4.3.2 Détermination des parties accessibles

4.3.2.1 Généralités

S'il est prévu que l'utilisateur exécute des actions en utilisation normale, avec ou sans l'aide d'un outil (un tournevis, une pièce, une clef, etc.), qui augmentent l'accessibilité des parties, ces actions doivent être exécutées avant d'effectuer les examens décrits du 4.3.2.2 au 4.3.2.3. Voici quelques exemples d'actions:

- retirer les capots;
- régler les commandes;
- remplacer les pièces d'usure;
- enlever les pièces.

4.3.2.2 Examen général

Le doigt d'épreuve articulé (voir l'IEC 61032 et l'IEC 60529:1989) doit être appliqué dans toutes les positions possibles. Si une partie peut devenir accessible en appliquant une force, le doigt d'épreuve rigide (voir 6.2 de l'IEC 61010-1:2010 et de l'IEC 61010-1:2010/AMD1:2016) doit être appliqué avec une force de 10 N. La force doit être exercée par la pointe du doigt d'épreuve pour éviter l'effet de coin et de levier. L'essai doit être appliqué à toutes les surfaces extérieures, y compris le fond.

4.3.2.3 Ouvertures pour les commandes pré réglées

Une aiguille d'épreuve en métal de 3 mm de diamètre (force de 10 N appliquée) doit être insérée dans les trous de l'enveloppe du matériel prévus pour accéder aux commandes pré réglées qui exigent l'utilisation d'un tournevis ou d'un autre outil. L'aiguille d'épreuve doit être appliquée dans toutes les directions possibles à travers le trou; des informations supplémentaires peuvent être obtenues dans l'IEC 61010-1. La pénétration ne doit pas dépasser trois fois la distance entre la surface de l'enveloppe du matériel et la manette de commande ou 100 mm, si cette distance est plus courte.

4.3.2.4 Parties TBT ou parties actives accessibles lorsque le capot est retiré

Si des parties TBT ou des parties sous tension, telles que des batteries remplaçables ou des contacts de relais électromécaniques, sont accessibles quand le capot est retiré sans l'aide d'un outil, une étiquette d'avertissement, visible lorsque le couvercle est retiré, est nécessaire. Cet avertissement doit comporter le symbole 14 et/ou le symbole 12 du Tableau 12.

4.3.2.5 Bornes de câblage

Les bornes de câblage accessibles en utilisation normale, par exemple les bornes situées à l'avant d'un produit, doivent satisfaire à l'exigence du Tableau 1.

Les bornes pour fils électriques qui se trouvent derrière un panneau, ou dans une zone à accès limité, et qui ne peuvent être touchées en utilisation normale doivent être considérées comme étant non accessibles. Cependant, au moins une protection de type IP1X conformément au 5.1 de l'IEC 60529:1989 doit être mise en place afin d'éviter un choc électrique dû à un contact accidentel.

Si la protection est de type IP0X ou IP1X, conformément au 5.1 de l'IEC 60529:1989, le symbole d'avertissement 12 du Tableau 12 doit être utilisé à proximité des bornes de câblage actives dangereuses accessibles.

La conformité du 4.3.1 au 4.3.2.5 doit être démontrée par essai.

4.3.3 Limites admissibles pour les parties accessibles

4.3.3.1 Généralités

La tension, l'intensité, la charge ou l'énergie entre une partie accessible et la terre d'essai de référence, ou entre deux parties accessibles d'un même matériel (sur une surface ou dans l'air), ne doit pas dépasser les valeurs du 4.3.3.2 en utilisation normale ni celles du 4.10.4.1.2 en condition de premier défaut.

4.3.3.2 Valeurs en utilisation normale

Les valeurs en utilisation normale sont données ci-dessous. Les tensions au-dessus des niveaux en a) sont considérées comme étant actives dangereuses si l'un des niveaux en b) ou c) est dépassé en même temps.

a) Niveaux de tension: 30 V en valeur efficace en courant alternatif ou 60 V en courant continu

Pour les matériels assignés pour une utilisation dans des emplacements humides (dispositif et/ou opérateur dans un emplacement humide du fait de la pluie, de la condensation, etc.), les niveaux de tension sont de 16 V en valeur efficace en courant alternatif ou de 35 V en courant continu.

b) Les niveaux de courant en utilisation normale sont indiqués dans le Tableau 2.

Tableau 2 – Niveaux de courant en utilisation normale

Emplacement de l'installation	Figure 3 ou Figure 4 de l'IEC 60990:2016 Circuit de mesure à utiliser	Ondes sinusoïdales mA en valeur efficace	Ondes non sinusoïdales ou à fréquence mixte mA crête	mA en courant continu
Sec	Figure 4	0,5	0,7	2
Humide	Figure 3 avec $R_S = 375 \Omega$ (au lieu de $1\,500 \Omega$)	0,5	0,7	2
Sec	Figure 3 avec $R_B = 75 \Omega$ Se réfère à de possibles brûlures dans la plage de fréquences de 30 kHz à 500 kHz	70	-----	-----

- c) Après avoir désactivé le matériel, les condensateurs doivent être déchargés dans un délai de 5 s jusqu'à une charge résiduelle indiquée dans le Tableau 3 ou jusqu'à une tension inférieure ou égale à 20 V. Dans le cas d'un matériel installé, lorsque la tension aux dispositifs de prise mâle et femelle peut être touchée et que ces dispositifs peuvent être débranchés alors qu'ils sont sous tension sans l'aide d'outils, les condensateurs doivent être déchargés en 1 s.

En ce qui concerne les deux cas de décharge ci-dessus, la vérification doit se faire par calcul de l'énergie (capacité totale dans le circuit) ou par mesurage de la tension, 5 s ou 1 s après avoir désactivé le matériel.

Si les paramètres ci-dessus ne peuvent pas être respectés en raison de contraintes de conception, un avertissement doit être facilement visible sur le matériel et signaler qu'il convient de décharger les condensateurs en toute sécurité pendant la mise hors service (symbole 14 du Tableau 12).

Tableau 3 – Charge ou énergie des niveaux de capacité en utilisation normale

Niveau maximal	Pour les tensions de crête ou en courant continu
45 μC	Jusqu'à 15 kV
350 mJ	$\geq 15 \text{ kV}$
NOTE La Figure 3 de l'IEC 61010-1:2010 représente la tension maximale acceptable pour la valeur de capacité, en utilisation normale comme en condition de premier défaut.	

4.4 Exigences de mise à la terre et de liaison de protection

4.4.1 Généralités

La mise à la terre d'un matériel peut être exigée pour des raisons de sécurité du personnel ou pour réduire les effets des perturbation électromagnétiques. Lorsqu'il y a conflit entre ces deux exigences, la sécurité des personnes doit toujours primer. L'organisation acceptable des moyens de protection contre les chocs électriques est représentée à la Figure 4 de l'IEC 61010-1:2010.

4.4.2 Isolation entre parties actives et parties conductrices accessibles

Les parties conductrices accessibles doivent être reliées à la borne du conducteur de terre de protection si elles peuvent devenir actives et dangereuses en l'absence d'un premier défaut des moyens de protection primaires spécifiés en 4.1. Sinon, ces parties accessibles doivent être séparées des parties qui sont actives et dangereuses par un écran de protection conducteur ou une barrière reliée à la borne de conducteur de terre de protection. Pour les dispositifs de mesure et de protection, une liaison indirecte est admise comme alternative à la liaison directe.

Il n'est pas nécessaire de relier les parties conductrices accessibles non reliées à la terre (telles que les portes ou les volets, les poignées, etc.) au conducteur de terre de protection si elles sont séparées de toutes les parties actives dangereuses par une double isolation ou par une isolation renforcée.

Le matériel de classe de protection I doit avoir au minimum une isolation principale entre les parties conductrices accessibles reliées au conducteur de terre de protection et les parties actives, à condition que l'isolation ne puisse pas être réduite au-dessous de l'isolation principale en condition de premier défaut, y compris l'impact mécanique, les câbles détachés, les bornes desserrées, etc. Une rétention mécanique peut être utilisée pour assurer le maintien de l'isolation principale en condition de premier défaut. Les vis ou les écrous avec des rondelles de sécurité ne sont pas considérés comme susceptibles de se desserrer, pas plus que les fils qui sont fixés mécaniquement par plus d'une seule soudure.

La vérification doit être réalisée par mesurage, en cas de doute concernant la conformité.

4.4.3 Liaison de protection

4.4.3.1 Généralités

Les parties conductrices accessibles doivent être reliées au conducteur de protection; cela n'est cependant pas essentiel lorsqu'une des conditions suivantes s'applique.

- Les parties conductrices accessibles non reliées à la terre sont exclusivement reliées à des circuits électriques avec déconnexion automatique de l'alimentation ou avec limite de courant ou de tension conformément au 4.3, et la tension ne dépasse pas les limites de la TBT (voir Annexe A).
- Les parties conductrices accessibles non reliées à la terre sont de dimensions réduites. En utilisation normale, elles ne sont pas destinées à être saisies, les probabilités de contact sont faibles et elles sont séparées des parties actives dangereuses par au moins une isolation principale.

Des informations supplémentaires sur l'organisation acceptable de la liaison de protection contre les chocs électriques peuvent être obtenues en consultant la Figure 4 de l'IEC 61010-1:2010.

4.4.3.2 Liaison des parties connectées au conducteur de protection

La conception du matériel doit assurer qu'aucune peinture ni aucun revêtement des surfaces à l'intérieur du circuit de liaison de protection à la terre n'altère la résistance de liaison de protection de ce circuit.

Voir 9.6.4.5 pour les exigences d'essai des liaisons de protection.

4.4.3.3 Protection contre la corrosion

Les parties conductrices en contact au niveau des bornes et des connexions de mise à la terre de protection doivent être choisies de sorte à réduire le plus possible la corrosion électrochimique entre les matériaux, quelles que soient les conditions d'environnement de fonctionnement, de stockage ou de transport, comme cela est indiqué dans les instructions fournies avec le matériel.

La résistance à la corrosion peut être obtenue par un processus adéquat de placage ou de revêtement.

La conformité au 4.4.3.3 est vérifiée par l'exécution de l'essai de type continu de chaleur humide (y compris les exigences d'essai de liaison de protection indiquées en 9.6.4.5).

4.4.3.4 Interruption de la liaison de protection

Lorsque la liaison de protection au sous-ensemble d'un matériel est réalisée par un dispositif de prise mâle et femelle actif ou conducteur, la liaison de protection ne doit pas être coupée avant les conducteurs sous tension. Lors de la reconnexion, la liaison de protection doit être reconnectée avant les conducteurs sous tension, ou à défaut en même temps que les conducteurs sous tension.

La conformité est vérifiée par examen et/ou par essai.

4.5 Circuits avec mise à la terre fonctionnelle

Si la mise à la terre fonctionnelle des parties accessibles est nécessaire, les règles suivantes s'appliquent.

- Il est admis de connecter le circuit avec mise à la terre fonctionnelle à une borne du conducteur de protection ou au conducteur de liaison de protection.
- Le circuit avec mise à la terre fonctionnelle doit être séparé des circuits TBT par au moins une isolation fonctionnelle.
- Le circuit avec mise à la terre fonctionnelle doit être séparé des circuits PEB et TBTP par au moins une isolation fonctionnelle.
- Le circuit avec mise à la terre fonctionnelle doit être séparé des parties actives dangereuses du matériel par l'un des moyens suivants:
 - double isolation ou isolation renforcée; ou
 - un écran de protection mis à la terre pour des raisons de protection, ou une autre partie conductrice mise à la terre pour des raisons de protection, séparé des parties dangereuses sous tension par au moins une isolation principale.

La conformité est vérifiée par examen, par mesurage et par essai.

4.6 Connexion du conducteur de protection

Les matériels qui ont une liaison de protection interne doivent avoir des moyens de connexion pour le conducteur de protection externe, de préférence près des bornes pour les conducteurs respectifs de mise sous tension.

La borne du conducteur de protection doit être résistante à la corrosion. Elle doit pouvoir accueillir des câbles d'une section au moins identique à celle du circuit du matériel avec les caractéristiques assignées les plus élevées de l'élément courant ou protection, qui peut causer un défaut de terre.

Les moyens de connexion pour le conducteur de protection ne doivent pas être utilisés comme une partie de l'assemblage mécanique du matériel.

La conformité est vérifiée par examen.

4.7 Courant de fuite élevé

Lorsqu'un matériel présente un courant de fuite continu de plus de 3,5 mA en valeur efficace en courant alternatif ou de 10 mA en courant continu en utilisation normale, le conducteur de protection doit être connecté comme pour un matériel connecté en permanence (voir Article E.2). Cela doit être indiqué dans la documentation du matériel.

Tous les mesurages de courant doivent être effectués en utilisant le circuit de mesure de la Figure 4 de l'IEC 60990:2016. Le matériel doit être isolé de la terre et du circuit de mesure connecté entre la borne du conducteur de protection et le conducteur de protection.

La conformité est vérifiée par mesurage.

4.8 Isolation solide

4.8.1 Généralités

L'isolation solide doit être conçue pour résister aux contraintes mécaniques, électriques, thermiques, climatiques et autres qui doivent être attendues en utilisation normale tout au long de la durée de vie du matériel.

L'isolation solide doit être conçue pour supporter les vibrations mécaniques ou les chocs qui peuvent se produire pendant le transport, le stockage et l'installation. La conformité aux exigences du 4.8.2 doit être vérifiée après les essais mécaniques du 9.6.2.1 et du 9.6.2.2.

L'isolation des fils doit être considérée comme une isolation solide.

Les matériaux fins et fragiles tels qu'un revêtement réalisé avec une laque ou par oxydation ou anodisation sont considérés comme étant insuffisants pour satisfaire à ces exigences.

La conformité au 4.8 est vérifiée par examen, par mesurage et par essai.

4.8.2 Exigences

La température maximale de l'isolation solide, en utilisation normale et à la température ambiante maximale, doit être inférieure à la température donnée pour la classe correspondante du Tableau 8 ou conformément au 6.10.2.

La conformité de l'isolation solide doit être vérifiée en effectuant des essais de type de tension diélectrique et de tension de choc, conformément à la catégorie appropriée de tension de service assignée et de surtension, déterminées à partir du tableau approprié du Tableau C.2 au Tableau C.11, et du Tableau C.12. La méthode d'essai doit être effectuée conformément à la méthode décrite en 9.6.4.2 et en 9.6.4.3. L'essai justifie uniquement la distance minimale à travers l'isolation, et non la ligne de fuite le long de la surface de l'isolation.

4.9 Distances d'isolement et lignes de fuite

4.9.1 Généralités

Les distances d'isolement et les lignes de fuite doivent être déterminées à partir du tableau approprié du Tableau C.2 au Tableau C.11; les distances d'isolement et les lignes de fuite peuvent être interpolées pour les tensions supérieures à 300 V.

La ligne de fuite minimale ne doit pas être inférieure à la distance d'isolement minimale. Ces distances d'isolement et ces lignes de fuite sont des valeurs minimales; les tolérances de fabrication doivent en plus être prises en compte.

Des exemples pour la conception et le mesurage des distances d'isolement et des lignes de fuite sont donnés en 6.2 de l'IEC 60664-1:2020.

Des champs non homogènes s'appliquent généralement au matériel.

Pour l'isolation fonctionnelle des formes d'onde de la tension pulsatoire, la valeur efficace de la tension de la forme d'onde doit être calculée et utilisée comme tension de service pour déterminer les distances d'isolement et les lignes de fuite exigées. Il convient que l'amplitude des tensions de crête répétitives de courte durée (définie comme étant inférieure à 2 % de la durée du cycle de la forme d'onde) ne dépasse pas 175 % de la valeur efficace assignée de la tension de service utilisée pour déterminer la ligne de fuite minimale.

En cas de doute sur la conformité des distances d'isolement et des lignes de fuite exigées, des mesurages doivent être effectués.

Si cela est approprié, des essais de type et des essais individuels de série des distances d'isolement doivent être réalisés pour déterminer la conformité au 4.9, conformément à l'Article 9.

4.9.2 Distances d'isolement

4.9.2.1 Généralités

Les distances d'isolement sont spécifiées pour supporter la surtension transitoire maximale qui peut être présente dans le circuit, soit à cause d'un événement extérieur (comme la foudre ou un phénomène transitoire), soit à cause du fonctionnement du matériel. Les distances d'isolement doivent être déterminées en référence à l'Annexe A et à l'Annexe C. Pour les distances d'isolement des circuits primaires, il convient de se référer également au Tableau B.1.

La distance d'isolement entre deux circuits doit être fondée sur la surtension transitoire maximale qui provient de l'un ou l'autre des circuits.

Pour maintenir la sécurité du produit, les distances d'isolement du matériel à des altitudes supérieures à 2 000 m doivent être multipliées par le facteur donné dans le Tableau 4.

Tableau 4 – Facteur de multiplication pour l'altitude

Altitude mètres	Facteur multiplicatif pour les distances d'isolement
2 000	1,00
3 000	1,14
4 000	1,29
5 000	1,48

Pour les altitudes de site d'essai autres que 2 000 m, les facteurs de correction correspondants de la tension d'essai sont donnés dans le Tableau C.12. Si nécessaire, prendre les mesures appropriées pour limiter les tensions transitoires auxquelles le matériel est soumis, par exemple utiliser des éclateurs ou des écrêteurs.

4.9.2.2 Distances d'isolement pour circuits primaires

Les distances d'isolement qui concernent les circuits primaires sont déterminées par la tension de choc assignée (voir C.1.4).

L'isolation principale est l'exigence minimale entre les circuits primaires et les autres circuits (circuits primaires ou non primaires) qui incluent les parties accessibles et les parties reliées à la terre. Une isolation supplémentaire (par exemple fonctionnelle ou supplémentaire) peut être exigée en fonction de la classe d'isolation (voir Annexe A). La conception de l'isolation fonctionnelle, comme celle d'un circuit primaire, doit être telle que le risque d'incendie soit réduit le plus possible.

Les valeurs des distances d'isolement sont indiquées à l'Annexe C. Pour les tensions assignées et les catégories d'installation autres que celles données dans les tableaux de l'Annexe C, se référer à l'Annexe F de l'IEC 60664-1:2020.

NOTE Les tensions de tenue données du Tableau C.2 au Tableau C.11 le sont pour des champs non homogènes. Dans de nombreux cas, la distance d'isolement entre deux parties du matériel se situe entre homogène et non homogène. Les distances d'isolement peuvent donc être prouvées par des essais.

4.9.2.3 Distances d'isolement pour circuits non primaires

Les distances d'isolement des circuits non primaires doivent supporter la surtension transitoire maximale qui peut être présente dans le circuit. Si des surtensions transitoires ne peuvent pas se produire, les distances d'isolement sont fondées sur la tension de service assignée.

Les valeurs des distances d'isolement sont indiquées à l'Annexe C. Pour les tensions de choc ou de service autres que celles données dans les tableaux de l'Annexe C, se référer à l'Annexe A de l'IEC 60664-1:2020.

4.9.3 Lignes de fuite

Il est admis par hypothèse que le matériel dont il est question dans le présent document est soumis à des contraintes de tension continues sur une longue période, ce qui exige la conception de lignes de fuite appropriées.

Les lignes de fuite doivent être déterminées par référence à l'Annexe A et l'Annexe C.

Des exemples pour la conception et le mesurage des lignes de fuite sont donnés en 5.2 et en 6.2 de l'IEC 60664-1:2020.

La ligne de fuite entre deux circuits doit être fondée sur la tension de service maximale sur la ligne de fuite (en général, la somme des tensions de ces circuits).

Si un degré de pollution 3 ou 4 provoque une conductivité persistante, par exemple à cause de poussières de charbon ou de métal, les dimensions des lignes de fuite ne peuvent pas être spécifiées. Au lieu de cela, la surface d'isolation doit être conçue pour éviter un chemin continu de pollution conductrice (par exemple au moyen de côtes ou de sillons, comme cela est spécifié en 5.2.5 de l'IEC 60664-1:2020).

Le Tableau C.13 indique la protection supplémentaire qui peut être utilisée pour réduire le degré de pollution à l'intérieur du matériel. Si le Tableau C.13 est utilisé pour déterminer une ligne de fuite réduite, il convient de s'assurer que celle-ci est d'au moins la distance d'isolement minimale admise.

En cas de doute, la conformité des lignes de fuite au 4.9.3 doit être vérifiée par mesurage. La conformité des lignes de fuite ne peut pas être vérifiée par des essais de tenue en tension.

L'interpolation des lignes de fuite des tableaux de l'Annexe C est admise, à la fois pour les circuits primaires et non primaires.

4.10 Conditions de premier défaut

4.10.1 Essais en condition de premier défaut

Le matériel ne doit pas présenter de risque de choc électrique ou d'incendie après un essai de condition de premier défaut. Il n'est pas exigé d'appliquer une condition de premier défaut à une double isolation ou à une isolation renforcée. Il n'est pas nécessaire qu'il soit fonctionnel après l'essai.

Les exigences suivantes s'appliquent.

- Les conditions de défaut susceptibles d'engendrer des dangers de choc électrique ou d'incendie, généralement révélées par l'examen du matériel et de son schéma de principe, doivent être appliquées.
- Des essais de panne doivent être effectués, sauf s'il peut être démontré qu'il est improbable qu'un danger découle d'une condition de premier défaut particulière.
- Le matériel doit être mis en fonctionnement avec la combinaison la moins favorable des conditions d'essai de référence.

Ces conditions incluent le cas le plus défavorable de tolérance de tension et de courant assignés, le cas le plus défavorable d'orientation du matériel, si les capots ou autres parties amovibles ne sont pas en place en utilisation normale, la valeur assignée maximale spécifiée des fusibles externes.

NOTE Les petites pièces telles que les vis et les rivets inaccessibles, isolées des circuits qui présentent des tensions actives dangereuses par au moins une isolation principale, ne sont pas prises en considération.

Une alternative aux essais de protection contre la propagation du feu en condition de premier défaut est donnée en 6.10, mais elle ne s'applique pas aux dangers de choc électrique.

4.10.2 Application d'une condition de premier défaut

4.10.2.1 Généralités

Les conditions de premier défaut doivent être appliquées l'une après l'autre. Elles doivent être appliquées tour à tour, dans l'ordre le plus commode. L'application simultanée de plusieurs défauts ne doit pas avoir lieu. Ils peuvent cependant se produire en conséquence de l'application d'une condition de premier défaut. L'application d'un premier défaut peut placer le matériel dans un état dangereux et il convient que le personnel qui réalise les essais prenne des précautions appropriées, telles que l'utilisation d'écrans de protection.

Après l'application d'une condition de premier défaut, le matériel ou la partie concernée doit être conforme aux exigences du 4.10.4.

L'évaluation d'une condition de premier défaut doit inclure les éléments suivants.

4.10.2.2 Impédance de protection

Les exigences suivantes s'appliquent.

- Si l'impédance de protection est formée par une combinaison de composants, chaque composant doit être court-circuité ou déconnecté à tour de rôle.
- Si l'impédance de protection est formée par une combinaison d'isolation principale et d'un appareil de limitation de la tension ou du courant, tant l'isolation principale que l'appareil de limitation de la tension ou du courant doivent être soumis à des premiers défauts, appliqués un par un. L'isolation principale doit être court-circuitée. L'appareil de limitation de la tension ou du courant doit être court-circuité ou déconnecté, si cette situation est moins favorable.

Il n'est pas nécessaire de court-circuiter ou de déconnecter les parties d'une impédance de protection qui représentent des composants de haute intégrité.

4.10.2.3 Transformateurs

Les enroulements non primaires des transformateurs et les sections des enroulements en dérivation qui sont en charge en utilisation normale doivent être soumis aux essais tour à tour, l'un après l'autre, pour simuler des courts-circuits dans la charge. Tous les autres enroulements sont en charge ou non, si cette situation de charge est moins favorable.

Un court-circuit doit être appliqué entre les enroulements primaires et non primaires du transformateur, sauf s'ils sont séparés par une isolation renforcée ou double. L'isolation renforcée ou la double isolation doit être soumise à des essais lorsque l'endommagement thermique sur l'isolation peut créer un risque de choc électrique.

Les courts-circuits doivent aussi être réalisés du côté charge de l'impédance de limitation du courant ou du dispositif de protection contre les surintensités qui sont connectés directement à l'enroulement.

4.10.2.4 Sorties

Les sorties doivent être court-circuitées une par une.

4.10.2.5 Isolation entre les circuits et les parties

L'isolation fonctionnelle entre les circuits et les parties doit être court-circuitée là où cela pourrait provoquer la surchauffe d'un matériau et créer un risque d'incendie, à moins que ce matériau soit de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux.

L'isolation principale des circuits primaires doit être shuntée pour éviter la propagation du feu.

Il n'est pas nécessaire de court-circuiter une isolation supplémentaire, une isolation renforcée et une double isolation, sauf lorsque l'endommagement thermique de l'isolation peut créer un risque de choc électrique.

4.10.2.6 Circuits primaires et circuits non primaires à tension dangereuse

Les conditions de premier défaut doivent être appliquées en créant un circuit ouvert ou un court-circuit au niveau des composants dans les circuits primaires et non primaires à tension dangereuse, à l'intérieur du matériel, lorsque ceux-ci peuvent créer un risque de choc électrique ou d'incendie.

4.10.2.7 Surcharges

Les conditions de premier défaut doivent être appliquées lorsqu'une surcharge d'un circuit ou d'un composant peut créer un danger d'incendie ou de choc électrique. Cela inclut la connexion des impédances de charge les plus défavorables aux bornes et connecteurs qui fournissent de la puissance ou des sorties de signal depuis le matériel.

Il est admis d'utiliser des fusibles thermiques, des dispositifs de protection contre les surintensités et autres pour obtenir une protection adéquate.

Lorsqu'il existe plusieurs accès avec le même circuit interne, l'essai de condition de premier défaut peut être limité à un seul accès.

4.10.2.8 Résistances à régime intermittent

La dissipation continue dans les résistances conçues pour une dissipation intermittente doit être examinée par une évaluation des conditions de premier défaut.

4.10.2.9 Entrées en courant continu

Les effets de la polarité inverse sur les entrées en courant continu doivent être évalués dans les conditions les plus défavorables.

Il est admis d'utiliser des fusibles thermiques, des dispositifs de protection contre les surintensités et autres pour obtenir une protection adéquate.

Lorsqu'il existe plusieurs accès avec le même circuit interne, l'essai peut être limité à un seul accès.

4.10.3 Durée des essais

Le matériel doit être mis en fonctionnement jusqu'à ce que toute modification supplémentaire qui résulte du défaut appliqué soit improbable. Chaque essai est normalement limité à une heure, car un défaut secondaire qui découle d'une condition de premier défaut se manifeste habituellement dans ce laps de temps. En présence d'une indication qu'un risque de choc électrique, une propagation du feu ou une blessure physique peut éventuellement se produire, par exemple si la température ne s'est pas stabilisée, l'essai doit se poursuivre pendant un laps de temps maximal de quatre heures, à moins qu'un danger ne se produise avant.

4.10.4 Conformité

4.10.4.1 Conformité aux exigences pour la protection contre les chocs électriques

4.10.4.1.1 Généralités

Un essai de tenue de tension diélectrique conforme au 9.6.4.3 doit être réalisé avant et après un essai de condition de premier défaut pour démontrer que le matériel ne présente pas de danger de choc électrique après l'application d'une condition de premier défaut.

Les circuits PEB, TBTP et TBTS doivent rester sûrs au toucher après l'application d'une condition de premier défaut.

A la suite d'une condition de premier défaut, les parties accessibles ne doivent pas devenir actives et dangereuses, comme cela est défini en 4.10.4.1.2.

4.10.4.1.2 Valeurs en condition de premier défaut

Les valeurs en conditions de premier défaut sont données ci-dessous. Les tensions au-dessus des niveaux en a) sont considérées comme étant actives dangereuses si l'un des niveaux en b) ou c) est dépassé en même temps.

- a) Les niveaux de tension sont de 50 V en valeur efficace en courant alternatif ou de 120 V en courant continu.

Pour les tensions de courte durée, les niveaux durée-tension sont ceux de la Figure 2 de l'IEC 61010-1:2010/AMD1:2016, mesurés à travers une résistance de 50 k Ω .

Pour un matériel assigné pour une utilisation dans des emplacements humides, les niveaux de tension sont de 33 V en valeur efficace en courant alternatif ou de 70 V en courant continu.

- b) Les niveaux de courant sont ceux indiqués dans le Tableau 5.

Tableau 5 – Niveaux de courant en condition de premier défaut

Emplacement de l'installation	Figure 3 ou Figure 4 de l'IEC 60990:2016 Circuit de mesure à utiliser	Ondes sinusoïdales mA en valeur efficace en courant alternatif	Ondes non sinusoïdales ou à fréquence mixte mA crête en courant continu	mA en courant continu
Sec	Figure 4	3,5	5	15
Humide	Figure 3 avec $R_S = 375 \Omega$ (au lieu de 1 500 Ω)	3,5	5	15
Sec	Figure 3 avec $R_B = 75 \Omega$ Se réfère à de possibles brûlures dans la plage de fréquences de 30 kHz à 500 kHz	500	-----	-----

- c) Le niveau de capacité est celui défini dans la Figure 3 de l'IEC 61010-1:2010.

4.10.4.2 Conformité aux exigences pour la protection thermique

Se référer au 6.3.1.

4.10.4.3 Conformité aux exigences pour la protection contre la propagation du feu

Se référer au 6.10.3.

4.10.4.4 Conformité aux exigences pour les gaz et les produits chimiques dangereux

Se référer au 6.3.2.

4.10.4.5 Conformité aux exigences pour la protection mécanique

La conformité aux exigences de protection mécanique est vérifiée par examen, afin de s'assurer qu'aucune pièce n'est expulsée par le matériel en raison de l'explosion ou de l'implosion d'une partie et qu'aucun danger mécanique n'est provoqué par l'application d'une condition de premier défaut.

Il convient que les dispositifs de protection contre les pièces expulsées ne soient pas amovibles sans l'aide d'un outil. Si le dispositif de protection est amovible sans l'aide d'un outil, le symbole 14 du Tableau 12 doit être utilisé, et un avertissement approprié doit être fourni dans la documentation.

5 Aspects mécaniques

5.1 Protection contre les dangers mécaniques

5.1.1 Stabilité

En conditions d'utilisation normale, le matériel ne doit pas devenir physiquement instable au point de devenir un danger pour l'utilisateur.

La conformité de la stabilité est vérifiée par examen.

5.1.2 Parties mobiles

Les parties mobiles ne doivent pas être capable d'écraser, de couper ou de percer des parties du corps de l'utilisateur susceptibles d'entrer en contact avec elles, ni de pincer gravement la peau de l'utilisateur en utilisation normale et en utilisation de maintenance. Cette exigence ne s'applique pas aux parties mobiles faciles à toucher qui sont à l'évidence destinées à fonctionner sur des parties de matériaux extérieurs au matériel, par exemple un mécanisme de déclenchement. Il convient que ce matériel soit conçu pour réduire le plus possible le contact par inadvertance avec ces parties mobiles (par exemple en installant des protections, des poignées, etc.).

La conformité des parties mobiles est vérifiée par examen.

5.1.3 Bords et coins

Il convient que tous les bords, projections, coins, ouvertures, protections, poignées et autres éléments similaires de l'enveloppe du matériel facilement touchés soient lisses et arrondis, de façon à ne pas provoquer de blessures en utilisation normale.

La conformité des bords et des coins est vérifiée par examen et, si nécessaire, par l'application d'un objet qui représente un doigt (taille, forme et dureté), afin de vérifier les abrasions et les coupures.

NOTE Une procédure acceptable qui peut être utilisée est décrite dans l'UL 1439.

5.2 Exigences mécaniques

Le matériel doit, lorsqu'il est monté conformément aux instructions du fabricant, satisfaire aux essais mécaniques décrits du 9.6.2.1 au 9.6.2.4.

Lorsque des niveaux de sévérité plus élevés sont nécessaires, ils doivent faire l'objet d'un accord entre le fabricant et l'utilisateur.

5.3 Sécurité mécanique des terminaisons

Se référer à l'Annexe E.

6 Inflammabilité et résistance au feu

6.1 Généralités

Le présent Article 6 contient les méthodes et les procédures pour réduire le risque d'incendie associé au matériel jusqu'à un niveau sûr par l'un des moyens suivants:

- en éliminant ou en réduisant les sources d'inflammation à l'intérieur du matériel;
- en réduisant la quantité de matériaux combustibles (ou inflammables) fournis dans le matériel;
- en confinant un incendie à l'intérieur du matériel, le cas échéant.

6.2 Exigences pour la protection contre la propagation du feu

Il est possible que le matériel ou des parties du matériel provoquent des températures excessives en utilisation normale ou en condition de premier défaut qui peuvent conduire à un risque d'incendie à l'intérieur du matériel ou autour de celui-ci.

Pour qu'il existe un risque d'incendie à l'intérieur du matériel, les trois éléments de base ci-dessous doivent exister.

- 1) Les circuits du matériel ont suffisamment de puissance ou d'énergie pour constituer une source d'inflammation.
- 2) De l'oxygène est présent (l'air contient environ 21 % d'oxygène).
- 3) Des matériaux combustibles sont présents pour soutenir le processus de combustion.

L'utilisation des méthodes et des procédures contenues dans le présent Article 6 offre les avantages suivants:

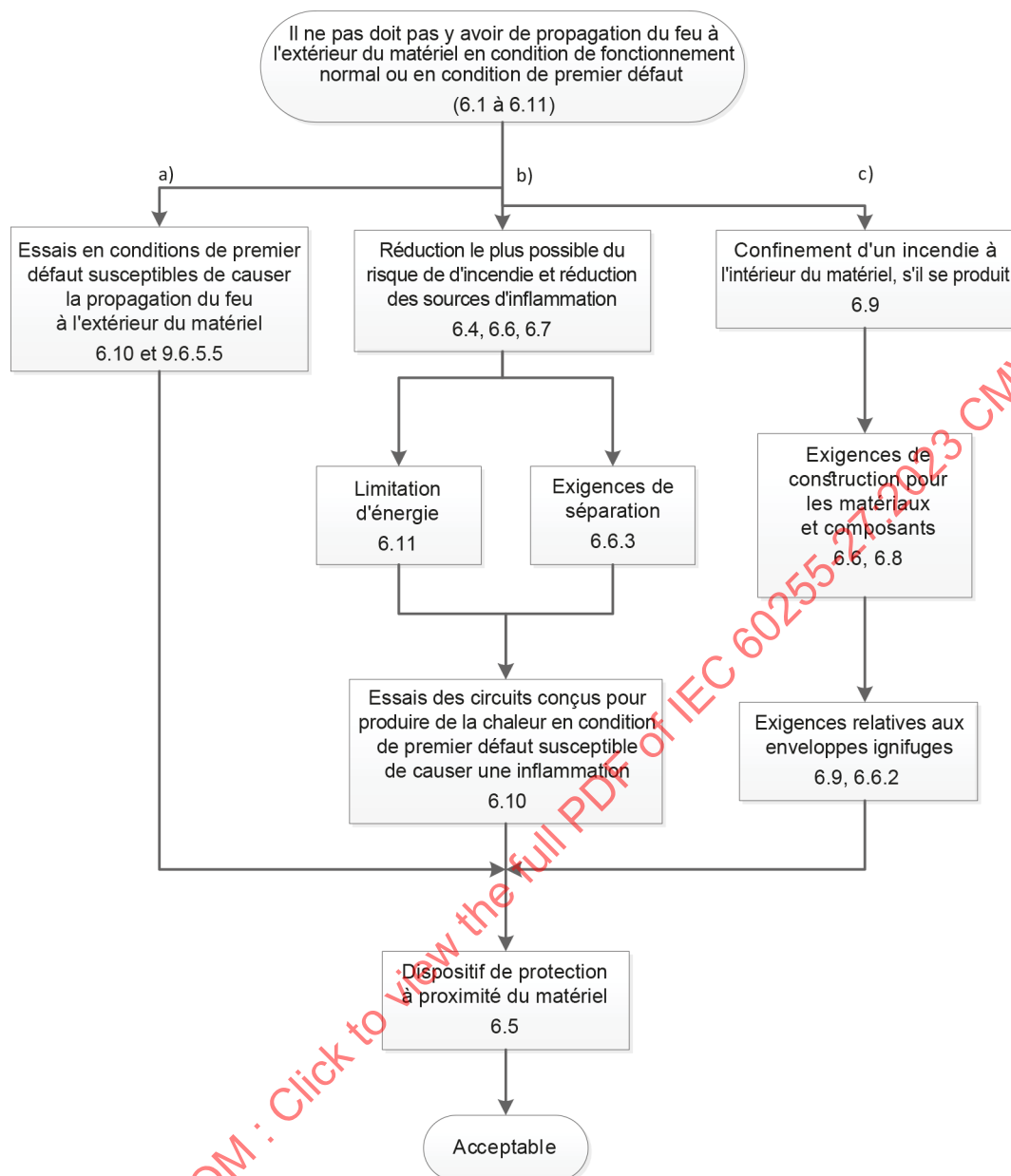
- conformité aux exigences de protection contre les incendies sans essai;
- réduction des essais en conditions de premier défaut;
- spécification de méthodes de fabrication qui permettent la vérification de la protection contre les incendies par examen;
- réduction des différences d'interprétation et des variables d'essai entre les autorités d'inspection.

L'Article 6 contient aussi le détail des exigences pour la protection contre la propagation du feu, les limites maximales de température et les circuits d'énergie limitée (voir 6.11).

Il ne doit exister aucune propagation du feu à l'extérieur du matériel en utilisation normale ou en condition de premier défaut. La Figure 1 représente un diagramme de flux qui décrit les méthodes de vérification de la conformité.

La conformité est vérifiée au regard des exigences applicables à un dispositif de protection (voir 6.5) et selon au moins l'une des méthodes suivantes.

- a) Essais en conditions de premier défaut (voir 6.10 et 9.6.5.5) qui peuvent provoquer une propagation du feu à l'extérieur du matériel. Les critères de conformité du 6.10.3 doivent être respectés.
- b) Vérifier l'élimination ou la réduction des sources d'inflammation à l'intérieur du matériel, comme cela est spécifié en 6.4.1 et en 6.4.2, ou en 6.4 et en 6.11.
- c) Vérifications conformément au 6.9 pour déterminer si un incendie qui se déclenche est confiné à l'intérieur du matériel.



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Figure 1 – Diagramme de flux qui représente les exigences pour la protection contre la propagation du feu

6.3 Dangers généraux de surchauffe et d'incendie

6.3.1 Limites de température de surface pour la protection contre les brûlures

L'échauffement ne doit pas représenter un danger en utilisation normale ou en conditions de premier défaut. Il ne doit pas non plus provoquer la propagation de l'incendie à l'extérieur du matériel. Le Tableau 6 spécifie les températures maximales acceptables en utilisation normale à la température ambiante maximale. Les températures du Tableau 6 peuvent être dépassées dans les conditions suivantes.

- Pour des zones qui sont peu susceptibles d'être touchées et dont les dimensions ne dépassent pas 50 mm, une température de 100 °C est admise.
- Les températures qui dépassent les limites qui sont données pour une température ambiante de 40 °C sont admises à condition qu'un contact non intentionnel soit improbable et que la partie porte un avertissement pour indiquer qu'elle est très chaude, par exemple le symbole 13 (ou 14) du Tableau 12.

Se référer au 4.10 pour les températures maximales acceptables en conditions de premier défaut.

Si des surfaces chauffées faciles à toucher sont nécessaires pour des raisons fonctionnelles, il est admis qu'elles dépassent les valeurs du Tableau 6, mais elles doivent être reconnaissables comme telles par leur apparence ou leur fonction, ou elles doivent porter un marquage. Il convient d'utiliser le symbole 13 du Tableau 12 pour indiquer qu'une surface ou une partie est chaude.

**Tableau 6 – Température maximale en utilisation normale
et à une température ambiante de 40 °C**

Parties accessibles en utilisation normale	Température maximale °C	
	Métal	Non métallique
Poignées, boutons, manchons, etc. tenus ou touchés uniquement pendant de courtes périodes	60	85
Poignées, boutons, manchons, etc. tenus continuellement en utilisation normale	55	70
Surfaces extérieures du matériel qui peuvent être touchées	70	80
Parties à l'intérieur du matériel qui peuvent être touchées	70	80

La conformité au 6.3.1 est vérifiée par mesurage et par examen des protections et des capots pour s'assurer qu'ils protègent contre un contact accidentel avec des surfaces à des températures qui dépassent les valeurs du Tableau 6. Toutes les protections et tous les capots doivent être en place pendant l'essai. Si les protections ou les capots peuvent être démontés sans l'aide d'un outil, les symboles 13 et 14 du Tableau 12 doivent être utilisés.

6.3.2 Gaz et produits chimiques dangereux

Le matériel ne doit pas libérer de quantités dangereuses de gaz toxiques ou nocifs en fonctionnement normal.

La documentation du fabricant doit indiquer quels gaz potentiellement toxiques ou nocifs peuvent être libérés, et en quelles quantités.

La conformité est vérifiée par examen de la documentation du fabricant. La grande variété de gaz rend impossible de spécifier des essais de conformité fondés sur des valeurs limites. Il convient donc de faire référence à des tables de valeurs seuils limites de risque professionnel.

6.4 Réduction des risques d'incendie

6.4.1 Généralités

La réduction le plus possible du risque d'incendie, tant à l'intérieur du matériel que pour les câbles et les canalisations électriques, doit faire l'objet d'une attention particulière. Une protection cohérente avec la fiabilité et les besoins opérationnels doit être procurée.

Dans l'éventualité d'une condition de premier défaut, tous les dommages doivent être confinés à l'intérieur du matériel (voir 6.10).

Les composants et les matériaux doivent être choisis et utilisés de telle façon que le risque d'incendie provoqué par la défaillance d'un composant ou par un éventuel court-circuit soit négligeable.

Il convient que les composants des circuits primaires et des circuits qui dépassent les limites de tension TBT critiques pour la sécurité soient conformes aux normes de composant applicables. Se référer à l'Annexe D pour plus d'informations. Le matériel et ses schémas de principe doivent être examinés pour déterminer si des essais de condition de premier défaut sont nécessaires pour démontrer que le risque d'incendie est négligeable.

6.4.2 Élimination ou réduction des sources d'inflammation à l'intérieur du matériel

6.4.2.1 Généralités

Le risque d'inflammation et d'incendie est réduit à un niveau tolérable si l'une des exigences suivantes est remplie pour chaque source d'inflammation dangereuse.

6.4.2.2 Puissance limitée

La tension, le courant et la puissance disponibles pour le circuit ou la partie du matériel sont limités comme cela est spécifié en 6.11. La conformité est vérifiée par mesurage des valeurs d'énergie limitée comme cela est spécifié en 6.11.

6.4.2.3 Isolation principale

L'isolation entre les parties à potentiels différents doit satisfaire aux exigences d'une isolation principale, ou il doit être démontré que le fait de court-circuiter l'isolation ne provoque pas d'inflammation. La conformité est vérifiée par examen ou par les essais appropriés du 9.6.5, en appliquant les critères du 6.10.

6.4.2.4 Sources d'inflammation

Les circuits du matériel qui ne peuvent pas être classés comme des circuits à énergie limitée (voir 6.11) sont considérés comme des sources d'inflammation, auquel cas la conformité est vérifiée par les essais appropriés du 9.6.5, en appliquant les critères du 6.10.

6.5 Câbles et fusibles

Le fabricant doit fournir les recommandations suivantes afin de réduire le plus possible le risque d'incendie et de surcharge thermique de l'alimentation en courant alternatif ou en courant continu et des conducteurs de protection ou autres matériels alimentés par le produit, en tenant compte des conditions de premier défaut les plus défavorables.

- Câbles de connexion: section et tension assignée minimales.
- Dispositifs de protection: caractéristiques assignées des fusibles ou des disjoncteurs. Il convient qu'ils se situent à proximité du matériel et il convient qu'ils incluent les caractéristiques du dispositif de protection et la tension assignée.

NOTE Les défaillances ou les défauts peuvent être dus à des courts-circuits dans le matériel ou à des parties conductrices accessibles, des défauts de terre, un court-circuit dans les circuits de sortie ou une défaillance du circuit de commande. Les câbles et les fusibles sont importants lorsque:

- dans les conditions d'utilisation prévues, une panne du matériel peut provoquer un dépassement du courant assigné de sortie du matériel, provoquant une surcharge thermique du conducteur de protection ou d'autres matériels alimentés par le matériel; et
- le défaut du matériel ne provoque pas automatiquement une déconnexion de son alimentation en courant alternatif ou en courant continu.

6.6 Inflammabilité des matériaux et des composants

6.6.1 Généralités

Voir le Tableau 14 pour une vue d'ensemble des essais, y compris d'inflammabilité.

La conformité est vérifiée par examen des données sur les matériaux ou par les essais d'inflammabilité spécifiés dans l'IEC 60695-11-10 sur trois échantillons des parties concernées (voir Tableau 14 et 9.6.5 du présent document). Les échantillons peuvent être les suivants:

- a) parties complètes et ensembles de matériaux tels qu'ils sont utilisés dans le produit;
- b) sections d'une partie, y compris la zone avec la moindre épaisseur de paroi et toutes les ouvertures de ventilation;
- c) échantillons conformes à l'IEC 60695-11-10.

Lorsque la sécurité est concernée, les composants doivent être conformes à l'une des catégories d'exigences suivantes:

- les exigences d'inflammabilité d'une norme de composant IEC applicable qui comprend ce type d'exigences;
- lorsqu'il n'existe pas de norme IEC applicable, les exigences d'inflammabilité du présent document;
- les exigences d'inflammabilité applicables d'une norme non IEC si celles-ci sont au moins aussi strictes que la norme IEC applicable, à condition que le composant ait été approuvé pour la norme non IEC par une autorité d'essai reconnue.

6.6.2 Matériaux des composants et des autres parties qui se trouvent à l'intérieur des enveloppes ignifuges

Les matériaux destinés à être utilisés à l'intérieur des enveloppes ignifuges doivent être conformes à l'un des points suivants.

- a) Composants électriques qui ne présentent pas un danger d'incendie en conditions anormales de fonctionnement s'ils sont soumis aux essais conformément au 4.10.
- b) Matériaux et composants qui se trouvent à l'intérieur de l'enveloppe du matériel d'un volume de 0,06 m³ ou moins, constitués entièrement de métal et sans ouvertures de ventilation, ou dans une unité hermétique qui contient un gaz inerte.
- c) Une ou plusieurs couches d'un matériau isolant mince, tel que du ruban adhésif, appliqué directement sur une surface quelconque à l'intérieur de l'enveloppe ignifuge, y compris la surface des parties porteuses de courant, à condition que la combinaison du matériau isolant mince et de la surface d'application soit conforme aux exigences sur la classe d'inflammabilité V-2 de l'IEC 60695-11-10 ou mieux. Lorsque le matériau isolant mince dont il est question dans l'exclusion ci-dessus se trouve sur la surface intérieure de l'enveloppe ignifuge elle-même, les exigences pour la construction des enveloppes ignifuges indiquées en 6.9 s'appliquent.
- d) Composants électroniques, tels que des ensembles de circuits intégrés, des ensembles d'optocoupleur, des condensateurs et autres petites parties montées sur matériau de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux.
- e) Fils, câbles et connecteurs isolés avec du PVC, TFE, PTFE, FEP, néoprène ou polyimide, ou fils isolés qui retardent la propagation des flammes, selon les exigences de performance recommandées dans les parties applicables de l'IEC 60332.

NOTE Les fils avec une classe d'inflammabilité UL 2556 VW-1 ou équivalente sont considérés comme satisfaisant à cette exigence.

- f) Pincés (à l'exclusion des bandes hélicoïdales ou autres formes continues), ruban de freinage, tressages et attaches de câble utilisés avec des faisceaux de câbles.

La conformité au 6.6.1 et au 6.6.2 est vérifiée par examen du matériel et des feuilles de données des matériaux.

6.6.3 Matériaux des enveloppes ignifuges

Les matériaux pour les composants qui remplissent une ouverture dans une enveloppe ignifuge et qui sont destinés à être montés sur cette ouverture doivent:

- être de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux; ou
- réussir l'essai d'inflammabilité de l'IEC 60695-11-10; ou
- être conformes aux exigences d'inflammabilité de la norme de composant IEC.

NOTE Les supports de fusibles, les interrupteurs, les connecteurs et les prises pour appareils sont des exemples de ces composants.

Les matériaux en plastique d'une enveloppe ignifuge doivent être situés à une distance de plus de 13 mm dans l'air des parties qui produisent des arcs électriques telles que les contacts de commutation qui ne se trouvent pas dans une enveloppe fermée.

Les matériaux plastiques d'une enveloppe ignifuge qui se trouvent à une distance de moins de 13 mm dans l'air des parties qui ne produisent pas d'arcs électriques et qui, en conditions de fonctionnement normal ou anormal, peuvent atteindre une température suffisante pour enflammer le matériau doivent être capables de réussir l'essai de l'IEC 60695-2-20. Le temps moyen d'inflammation des échantillons ne doit pas être inférieur à 15 s. Si un échantillon fond entièrement sans s'enflammer, le moment auquel cela se produit n'est pas considéré comme le temps d'inflammation.

La conformité au 6.6.3 est vérifiée par examen du matériel et des feuilles de données du matériau et, si nécessaire, par l'essai d'inflammabilité approprié.

6.6.4 Matériaux des composants et des autres parties qui se trouvent à l'extérieur des enveloppes ignifuges

Sauf indication contraire ci-dessous, les matériaux pour les composants et autres parties (y compris les enveloppes mécaniques, les enveloppes électriques et les parties décoratives) situés à l'extérieur des enveloppes ignifuges doivent avoir au minimum une inflammabilité de classe HB75 selon l'IEC 60695-11-10 si l'épaisseur significative la plus faible de ce matériau est <3 mm, ou une inflammabilité de classe HB40 selon l'IEC 60695-11-10 si l'épaisseur significative la plus faible de ce matériau est ≥ 3 mm, ou une inflammabilité de classe HBF. Lorsqu'une enveloppe mécanique ou électrique sert aussi d'enveloppe ignifuge, les exigences pour les enveloppes ignifuges s'appliquent (voir 6.6.3 et 6.9).

Les exigences d'inflammabilité ci-dessus ne s'appliquent pas aux éléments suivants:

- a) les composants électriques qui ne présentent pas un danger d'incendie en conditions anormales de fonctionnement s'ils sont soumis aux essais conformément au 4.10;
- b) les composants conformes aux exigences d'inflammabilité d'une norme de composant IEC applicable qui comprend ce type d'exigences;
- c) les composants électroniques, tels que les ensembles de circuits intégrés, les ensembles optocoupleurs, les condensateurs et autres petites pièces:
 - 1) montées sur un matériau de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux;
 - 2) alimentés par une source de puissance inférieure ou égale à 15 VA ou conforme aux exigences pour les circuits à énergie limitée (voir 6.11), en conditions de fonctionnement normal ou après une condition de premier défaut du matériel, et montés sur un matériau d'une inflammabilité de classe HB75 selon l'IEC 60695-11-10 si l'épaisseur significative la plus faible de ce matériau est < 3 mm, ou d'une inflammabilité de classe HB40 selon l'IEC 60695-11-10 si l'épaisseur significative la plus faible de ce matériau est ≥ 3 mm.

Les connecteurs doivent satisfaire à l'une des exigences suivantes:

- être faits d'un matériau de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux;

- réussir les essais de l'IEC 60695-11-10;
- être conformes aux exigences d'inflammabilité de la norme de composant IEC applicable;
- être situés dans un circuit secondaire alimenté par une source de puissance qui est limitée à une valeur maximale de 15 VA ou qui est conforme aux exigences pour les circuits à énergie limitée (voir 6.11) en conditions de fonctionnement normal et après une condition de premier défaut du matériel (voir 4.10).

Les plaques à bornes doivent satisfaire aux exigences suivantes:

- être faits d'un matériau de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux;
- respecter les limites de température pour le matériau concerné avec le courant de charge maximale appliqué.

6.7 Sources d'inflammation

Tous les circuits du matériel qui peuvent être classés comme incluant des circuits primaires ou des circuits qui dépassent les limites de tension TBT doivent être considérés comme une source d'inflammation. Tous les composants électriques de ces circuits sont aussi considérés comme une source possible d'inflammation.

6.8 Conditions pour une enveloppe ignifuge

6.8.1 Parties pour lesquelles une enveloppe ignifuge est nécessaire

Les parties suivantes sont considérées comme présentant un risque d'inflammation et nécessitent par conséquent une enveloppe ignifuge:

- a) composants des circuits primaires ou qui dépassent les limites de tension TBT, sauf si le matériel répond aux exigences de tous les essais de condition de premier défaut applicables du 4.10;
- b) composants des circuits non primaires alimentés par des sources de puissance qui dépassent les limites spécifiées en 6.11;
- c) composants des circuits non primaires alimentés par une source conforme aux spécifications du 6.11 pour les circuits à énergie limitée, mais non montés sur un matériau de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux;
- d) composants à l'intérieur d'une unité ou d'un assemblage d'alimentation qui a une sortie conforme aux spécifications du 6.11, pour les circuits à énergie limitée, qui comprennent des appareils de protection contre les surintensités, des impédances de limitation, des réseaux et câblages de régulation (voir 6.8.2 pour les exceptions), jusqu'au point de conformité aux critères de sortie de source pour un circuit à énergie limitée;
- e) composants avec des parties qui produisent des arcs électriques qui ne se trouvent pas dans une enveloppe fermée, tels que les interrupteurs et contacts de relais ouverts dans un circuit qui présente une tension dangereuse ou à un niveau dangereux d'énergie;
- f) câbles isolés, sauf ceux admis en 6.8.2.

6.8.2 Parties pour lesquelles une enveloppe ignifuge n'est pas nécessaire

Les parties suivantes n'exigent pas d'enveloppe ignifuge:

- a) moteurs;
- b) transformateurs;
- c) composants électromécaniques conformes au 6.6;
- d) composants, y compris les connecteurs, conformes aux exigences du 6.6.4, qui remplissent une ouverture dans une enveloppe ignifuge;
- e) fils et câbles isolés avec du PVC, TFE, PTFE, FEP, néoprène ou polyamide;
- f) prises et connecteurs qui font partie d'un câble d'alimentation ou d'un câble d'interconnexion;

- g) connecteurs des circuits non primaires alimentés par des sources qui sont limitées à une valeur maximale de 15 VA en conditions de fonctionnement normal et après une condition de premier défaut du matériel;
- h) connecteurs des circuits non primaires alimentés par des circuits à énergie limitée conformes au 6.11;
- i) autres composants des circuits non primaires:
 - 1) alimentés par un circuit à énergie limitée conforme au 6.11 et montés sur des matériaux de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux;
 - 2) alimentés par des sources intérieures ou extérieures limitées à 15 VA au maximum en conditions de fonctionnement normal et après une condition de premier défaut du matériel, et montés sur un matériau d'une inflammabilité de classe HB75 selon l'IEC 60695-11-10 si l'épaisseur significative la plus faible de ce matériau est < 3 mm, ou d'une inflammabilité de classe HB40 selon l'IEC 60695-11-10 si l'épaisseur significative la plus faible de ce matériau est ≥ 3 mm;
- j) matériel qui a passé tous les essais de condition de premier défaut applicables du 4.10 tant sur les circuits primaires que sur les circuits non primaires;
- k) petites parties, telles que des étiquettes papier, jusqu'à $1\,500\text{ mm}^2$.

Si les composants deviennent excessivement chauds en condition de premier défaut et sont montés à moins de 13 mm de matériaux non métalliques d'une inflammabilité de classe V-2 ou moindre, un essai d'allumage au fil incandescent selon l'IEC 60695-2-12 peut être effectué sur le matériau non métallique, d'épaisseur minimale, pour déterminer s'il existe un risque d'incendie.

La conformité au 6.8.1 et au 6.8.2 est vérifiée par examen et par évaluation des données fournies par le fabricant. Si aucune donnée n'est fournie, la conformité est vérifiée par des essais d'inflammabilité.

6.9 Enveloppes ignifuges et barrières contre les flammes

6.9.1 Généralités

Le risque d'incendie dans les circuits primaires et dans les circuits qui dépassent les limites TBT doit être considéré comme étant réduit jusqu'à un niveau tolérable si les circuits et l'enveloppe du matériel sont conformes aux exigences de construction du 6.9.

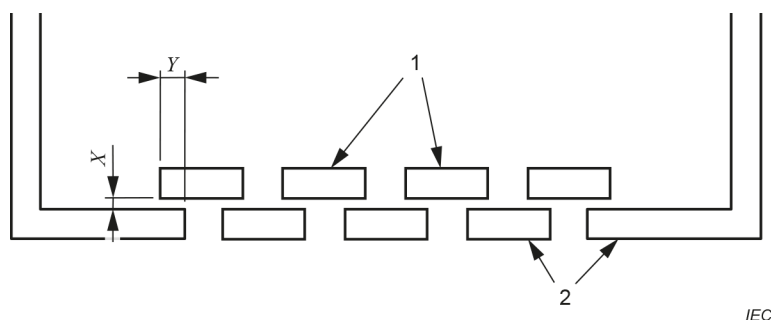
6.9.2 Exigences relatives aux enveloppes ignifuges et aux barrières contre les flammes

L'enveloppe ignifuge doit être conforme aux exigences suivantes.

- Le fond ne doit pas comporter d'ouvertures ou, dans la mesure indiquée à la Figure 3, il doit être construit avec des déflecteurs comme cela est spécifié à la Figure 2, ou être fait en métal perforé comme cela est spécifié dans le Tableau 7, ou être un écran de métal avec une maille qui ne dépasse pas $2\text{ mm} \times 2\text{ mm}$ de centre à centre et un diamètre de fil d'au moins $0,45\text{ mm}$.
- L'enveloppe du matériel, et tous les déflecteurs ou barrières contre les flammes, doivent être en métal (excepté le magnésium) ou en matériaux non métalliques de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux.
- L'enveloppe du matériel, et tous les déflecteurs ou toutes les barrières contre les flammes doivent présenter une résistance mécanique adéquate pour procurer la protection contre les chocs électriques conformément à l'Article 4.

Une barrière contre les flammes et le fond d'une enveloppe ignifuge sont considérés comme étant conformes sans essai si, dans l'épaisseur la plus mince utilisée, le matériau est de la classe d'inflammabilité V-1 de l'IEC 60695-11-10 ou mieux.

La conformité au 6.9 est vérifiée par examen. En cas de doute, la classe d'inflammabilité V-1, ou mieux, doit être vérifiée sur trois échantillons conformément à l'IEC 60695-11-10.

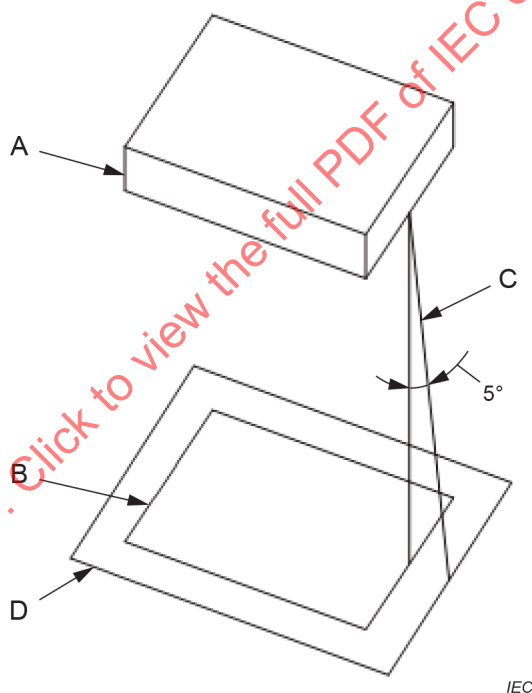


$Y = 2X$, mais jamais moins de 25 mm

Légende

- 1 plaques de déflecteur (peuvent se trouver sous le fond de l'enveloppe)
- 2 fond de l'enveloppe

Figure 2 – Déflecteur



Légende

- A partie ou composant du matériel qui est considéré comme une source de danger d'incendie. Il s'agit d'un composant entier ou d'une partie entière du matériel si celui-ci n'est pas blindé d'une autre manière, ou de la partie non blindée d'un composant qui est partiellement blindé par son enveloppe
- B projection du contour de A sur le plan horizontal
- C ligne oblique qui trace la surface minimale du fond et des côtés à concevoir comme cela est spécifié en 6.9. Cette ligne est projetée à un angle de 5° par rapport à la verticale en chaque point autour du périmètre de A et est orientée de façon à tracer la surface maximale
- D surface minimale du fond à concevoir comme cela est spécifié en 6.9

Figure 3 – Emplacement et extension d'une barrière contre les flammes

Tableau 7 – Perforations acceptables dans le fond d'une enveloppe de matériel

Épaisseur minimale	Dimension maximale des trous^a	Espacement minimal des trous de centre à centre
mm	mm	mm
0,76	1,15	1,70
0,76	1,19	2,36
0,81	1,91	3,18
0,89	1,90	3,18
0,91	1,60	2,77
0,91	1,98	3,18
1,00	1,60	2,77
1,00	2,00	3,00

^a La diagonale est la dimension maximale d'un trou carré.

6.10 Évaluation du risque d'incendie dû à une condition de premier défaut

6.10.1 Lignes directrices pour les températures maximales acceptables lorsqu'un circuit ou un composant est soumis à une condition de premier défaut

S'il n'est pas pratique de protéger les composants contre une surchauffe en condition de premier défaut, les composants doivent être montés sur des matériaux de classe d'inflammabilité V-1 ou mieux, selon l'IEC 60695-11-10. En complément, de tels composants doivent être isolés des matériaux de classes inférieures à la classe d'inflammabilité V-1 par au moins 13 mm dans l'air ou par une barrière solide constituée de matériau de classe d'inflammabilité V-1 ou mieux.

Les températures indiquées doivent être sur le point le plus chaud de la surface d'un composant ou d'un matériau, ou à l'intérieur de ceux-ci.

Lorsqu'il n'est pas possible de se conformer aux critères donnés ci-dessus pour les composants et/ou circuits soumis à une surchauffe en condition de défaut, il convient que ceux-ci soient efficacement blindés ou séparés pour éviter la surchauffe des matériaux et composants qui les entourent (voir 6.9). Sinon, il convient de soumettre le matériel monté en utilisation normale à l'essai de conformité du 6.10.3.

6.10.2 Température des enroulements en utilisation normale ou en condition de premier défaut

Si un danger peut être causé par une température excessive, la température du matériau d'isolation des enroulements ne doit pas dépasser les valeurs du Tableau 8 en utilisation normale ou en condition de premier défaut. Les valeurs du Tableau 8 ne s'appliquent pas aux surcharges à court terme. Si la température d'un enroulement est déterminée en utilisant des thermocouples, ces valeurs sont réduites de 10 °C, sauf dans le cas d'un enroulement avec thermocouples intégrés.

La conformité au 6.10.2 est vérifiée par mesurage en utilisation normale et dans la condition de premier défaut applicable.

Tableau 8 – Matériau isolant des enroulements

Classe d'isolation (définie dans l'IEC 60085)	Utilisation normale °C	Condition de premier défaut °C
Classe A	105	150
Classe B	130	175
Classe E	120	165
Classe F	155	190
Classe H	180	210

6.10.3 Conformité du matériel aux exigences pour la protection contre la propagation du feu

Se référer au 9.6.5.5 pour les essais de condition de premier défaut.

La conformité du matériel au 6.10.3 pour les exigences de protection contre la propagation du feu est vérifiée, en tant qu'essai de type de sécurité, en plaçant le matériel sur un papier mousseline (papier d'emballage entre 12 g/m² et 30 g/m²) qui couvre une surface de bois tendre et en couvrant le matériel avec une seule couche d'étamine (coton blanchi d'environ 40 g/m²). Aucun métal fondu, aucune isolation brûlée ou particule incandescente, etc. ne doit tomber sur la surface sur laquelle repose le matériel et il ne doit pas y avoir de carbonisation, de rougeoiement ni d'inflammation du papier mousseline ou de l'étamine. La fonte du matériau isolant qui est sans importance pour les exigences du présent document doit être ignorée.

6.11 Circuit à énergie limitée

Un circuit à énergie limitée est un circuit qui satisfait à l'ensemble des critères suivants.

- Le potentiel qui apparaît dans le circuit ne dépasse pas 30 V en valeur efficace en courant alternatif ou 60 V en courant continu.
- Le courant qui peut apparaître dans le circuit est limité de l'une des façons suivantes:
 - le courant maximal disponible est limité intrinsèquement ou par impédance de telle façon qu'il ne peut pas dépasser la valeur appropriée du Tableau 9;
 - le courant est limité par un dispositif de protection contre les surintensités conformément au Tableau 10;
 - un réseau de régulation limite le courant maximal disponible pour qu'il ne puisse pas dépasser la valeur appropriée du Tableau 9 en utilisation normale ou à la suite d'une panne du réseau de régulation.
- Il est séparé par au moins une isolation principale des autres circuits susceptibles d'entraîner des valeurs d'énergie qui dépassent les critères a) et b) ci-dessus.

Si un dispositif de protection contre les surintensités est utilisé, il doit s'agir d'un fusible ou d'un dispositif électromécanique non réglable et sans réenclenchement automatique.

La conformité au 6.11 est vérifiée par examen et par mesurage des potentiels qui apparaissent dans le circuit, du courant maximal disponible, dans les conditions suivantes.

- Les potentiels qui apparaissent dans le circuit sont mesurés dans la condition de charge qui augmente le plus possible la tension.
- Le courant de sortie est mesuré après 60 s de fonctionnement avec la charge résistive (y compris le court-circuit) qui produit la valeur de courant la plus élevée.